Metal PROGRESS

DECEMBER 1951

SCIENCE NEWS FOR YOUR HEAT-TREAT

For the first time, plant metallurgists can control carburizing by direct measurement of carbon in hot furnace gases.

Scientists have long known that the electrical resistance of a piece of steel will change whenever there's a change in the carbon content of the metal. This basic fact is now being put to work by many progressive metallurgists and heat-treaters. For L&N has applied the principle in a brand-new Primary Element called a Carbohm. In use, a Carbohm projects into the heat-treating furnace . . . looks rather like a thermocouple. Whenever the amount of active carbon in the furnace gas begins to increase or decrease, the Carbohm detects the change. An automatic controller connected to the Carbohm throttles the carbon supply up or down, to keep the furnace gas at desired strength. And a Micromax Recorder plots the result . . . as easy to read as a record of temperature.

The complete equipment—Carbohm, Controller and Recorder—is called Microcarb Control. Because the furnace and its temperature control must be designed to meet the needs of atmosphere regulation, Microcarb can be used only with the Series H Homocarb Furnace. It's our opinion—based on 35 years' experience in making fine heat-treating equipment—that any heat-treating department can do better work with Microcarb than by any other known means. And, because Microcarb adds another automatic control to the carburizing process, it should enable your plant to cut the costs of any carburized, mass-produced part or parts.

To top management, Microcarb means better competitive position for the individual company.

To production executives, Microcarb means closer following of production schedules, because carburizing speeds and results are definitely more predictable than ever before.

To personnel executives, Microcarb means cleaner, more attractive working conditions. And, if the heat-treat uses incentive pay, Microcarb helps heat-treaters increase their earnings, because it makes it easier for them to apply their skill and therefore increase their productivity.

To metallurgists, Microcarb means some or all of the above advantages, plus a tightening of technique such as every technician likes. "New" or hard-to-handle steels hold fewer puzzles. Standard steels emerge with closer specifications. The heat-treat takes another long step toward becoming a manufacturing laboratory.

Let us send you further facts about this new Microcarb Control. Just Check the coupon:

LEEDS & NORTHRUP CO.
4927 Stenton Ave., Phila. 44, Pa.

Please send Catalog T-623; Microcarb Control & Homocarb Furnaces

Please send Sec. 1 of Catalog T-623; Microcarb Control only

Name

Firm

Address

My title

LEEDS & NORTHRUP CO.

Electrical Measuring Instruments **Automatic Controls**
Heat-Treating Furnaces

Jrl Ad TD4-623(5)

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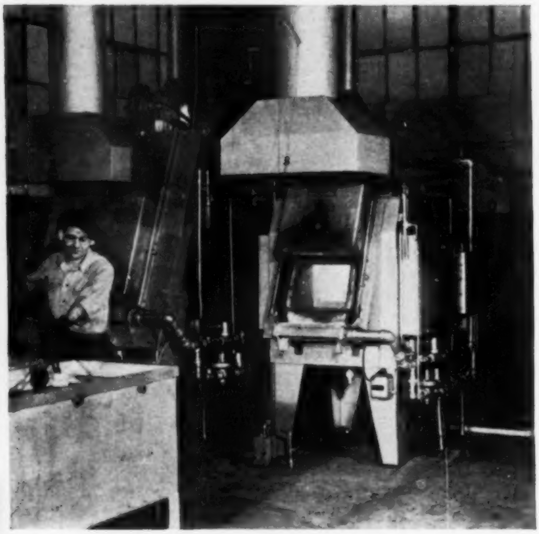
Here's why Super Refractories by CARBORUNDUM are used in nearly every heat-treating furnace



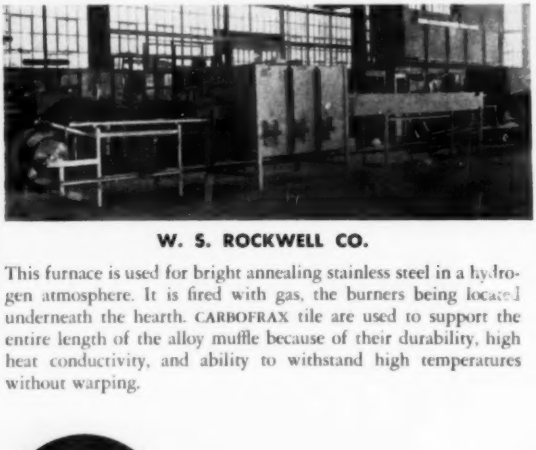
LINDBERG ENGINEERING CO.

Shown here is an electrically heated hydryzing furnace used for hardening high speed steel in controlled protective atmosphere. It operates at temperatures up to 2500° F. It has a CARBOFRAX silicon carbide hearth to resist the high temperatures and the abrasive action of the charge — also to prevent any spalling or cracking.

There's hardly a heat-treating furnace that, somewhere in the furnace, doesn't use Super Refractories by CARBORUNDUM.

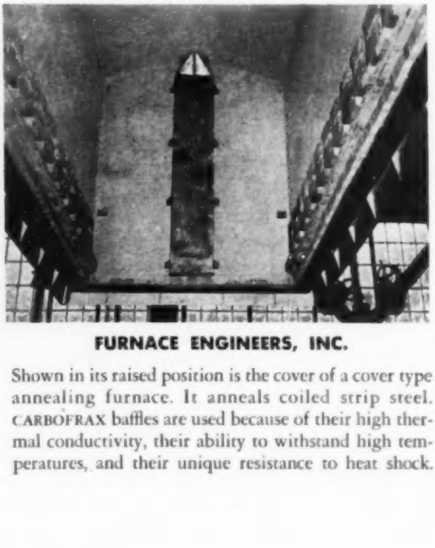
They're used in hearths and muffles to insure rapid and uniform heat *transfer* — for supports to keep the floor level even under heavy loads and at high temperatures — for floors to resist punishing abrasion — for burner parts and other parts to counteract flame erosion, spalling or cracking. They improve furnace efficiency, help deliver better quality work.

We have a free booklet which outlines many specific applications. You'll find its recommendations may prove highly profitable.



W. S. ROCKWELL CO.

This furnace is used for bright annealing stainless steel in a hydrogen atmosphere. It is fired with gas, the burners being located underneath the hearth. CARBOFRAX tile are used to support the entire length of the alloy muffle because of their durability, high heat conductivity, and ability to withstand high temperatures without warping.



FURNACE ENGINEERS, INC.

Shown in its raised position is the cover of a cover type annealing furnace. It anneals coiled strip steel. CARBOFRAX baffles are used because of their high thermal conductivity, their ability to withstand high temperatures, and their unique resistance to heat shock.

THE CARBORUNDUM COMPANY

Dept. C-121 Refractories Div. **Perth Amboy, New Jersey**

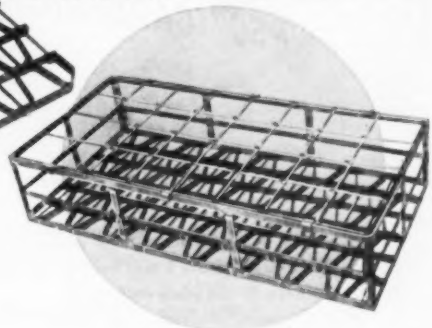
"Carborundum" and "Carbofrax" are registered trademarks which indicate manufacture by The Carborundum Company.

ROLOCK

FABRICATED ALLOYS

Introducing . . .

ROLOCK'S NEW "SERPENTINE"* GRID



Rolock engineers have designed this distinctly different "Serpentine" alloy grid to meet the rigid requirements of modern heat treating practices. It is very light in weight, yet capable of performing with minimum distortion for an extremely long service life . . . *never previously attained.*

Simple in design and fully articulated with loose tie rods, the grid is constructed with longitudinal bars as principal load carrying members, spaced with serpentine-like intermediate bars which serve to maintain vertical alignment.

Versatility of application is shown above. Inconel tray with positioning lugs used for copper brazing taurus assemblies at 2050°F. Basket, also of Inconel, used for annealing, quenching and acid pickling steel components in a continuous cycle. Full details on application.

*Patent applied for

Offices: PHILADELPHIA, CLEVELAND, DETROIT, HOUSTON, INDIANAPOLIS, CHICAGO, ST. LOUIS, LOS ANGELES, MINNEAPOLIS, PITTSBURGH

ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

for better work
Easier Operation, Lower Cost

7RL51

YOU CAN FIGURE ON 2 LABOR SAVINGS *with* "PSC" CARBURIZING FIXTURES

The rack pictured above is a typical example of how The Pressed Steel Co. is helping its customers, in two ways, to cut labor costs.

First, in parts handling. This fixture, with its removable trays, eliminated three complete handlings. The trays get their load of small parts at machine side. Without further handling they are trucked, carburized, quenched and then routed through finishing.

Second, because PSC welded alloy heat-treating equipment weighs 2/3 less than cast equipment, it handles easier and faster; in addition it requires less time to attain pot heat. A recent study of one customer's cycle showed a total saving of 5 hours.

Let our technical staff work with you in devising production savings. As pioneers of light-weight, sheet alloy heat-treating containers and fixtures, we make available to you a wealth of designing and production know-how. Whether you are installing new furnaces or need replacement equipment, let us send you information how PSC welded alloy units cut labor and fuel costs, and shorten heating cycles. We furnish standard or special welded alloy equipment in any size, and in any metal to meet your heat and corrosion requirements. Send blue prints or write as to your needs.

***Light-Weight* Heat-Treating Equipment for Every Purpose**

Carburizing and Annealing Boxes
Baskets - Trays - Fixtures
Muffles - Retorts - Racks
Annealing Covers and Tubes
Pickling Equipment

Tumbling Barrels - Tanks
Cyanide and Lead Pots
Thermocouple Protection Tubes
Radiant Furnace Tubes and Parts
Heat, Corrosion Resistant Tubing

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

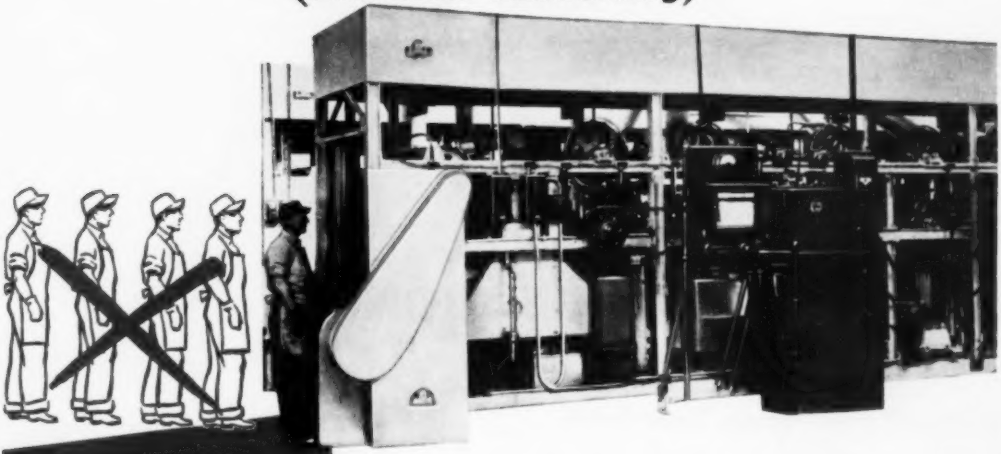
Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

CUT COSTS WITH THE

Fastest Carburizing

(and case hardening)



Labor Cost Reduced 80%

390 Lbs. of Work an Hour

. . . from an Ajax furnace no larger than your desk!

180 lbs. of metal body screws per charge are case hardened (0.004" to 0.010") as required.

More economical . . . is the fastest method of producing a specified case depth—for example, a case of 0.040 in. can readily be produced in 2 hours . . . No boxes or retorts to pack and unpack or to heat as dead loads.

Less distortion . . . temperature uniformity throughout bath guaranteed within 5°F. . . . less subsequent grinding . . . permits more shallow case depths.

Closer control of depth and other properties of the case.

Selective carburizing simplified by immersing only portions of work to be treated.

Eliminates usual reheating operation . . . work quenched directly from carburizing bath.

Extreme flexibility . . . several batches may be case hardened simultaneously—each to a different case depth.

No "oxygenation" of the case, with attendant pitting and spalling, as frequently occurs in gas or pack carburizing.

Readily adaptable to mechanization for efficient, low-cost mass production.

Combines with martempering . . . for best control of distortion . . . by an isothermal salt bath quench directly after carburizing.

Brazing can be performed simultaneously . . . both carburizing and brazing done with one heating of the work. Brazing cost—nothing.

Low maintenance costs . . . plain steel pots have a life of 1 to 3 years.

AJAX ELECTRIC COMPANY, INC.

910 Frankford Avenue, PHILADELPHIA 23, PA.

World's largest manufacturer of electric heat treating furnaces exclusively

In Canada: Canadian General Electric Co., Ltd., Toronto, Ont.

AJAX ELECTRIC SALT BATH FURNACES

TEN TIMES THE LIFE AND STILL GOING STRONG!

Ni-Hard† Pipe Proves Superiority in Resisting Abrasive Action

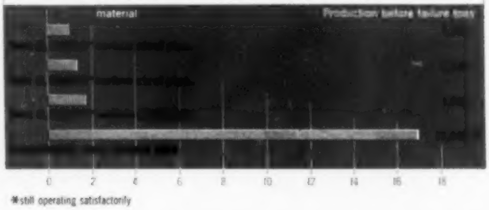
If your problem is abrasion, you'll be interested in this case history of Metal Mold centrifugally cast Ni-Hard pipe in action.

The McKee Glass Company, one of the nation's leading producers of molded glass for household and industry, uses a pneumatic conveyor system to handle its glass furnace charges. In this system tons of silica, sand, feldspar, borax, etc., are hurled at tornado-like speeds . . . about 100 miles per hour . . . through vacuum lines from boxcars to storage bins. Broken glass scrap (cullet) is added at the mixers to form a highly abrasive mixture.

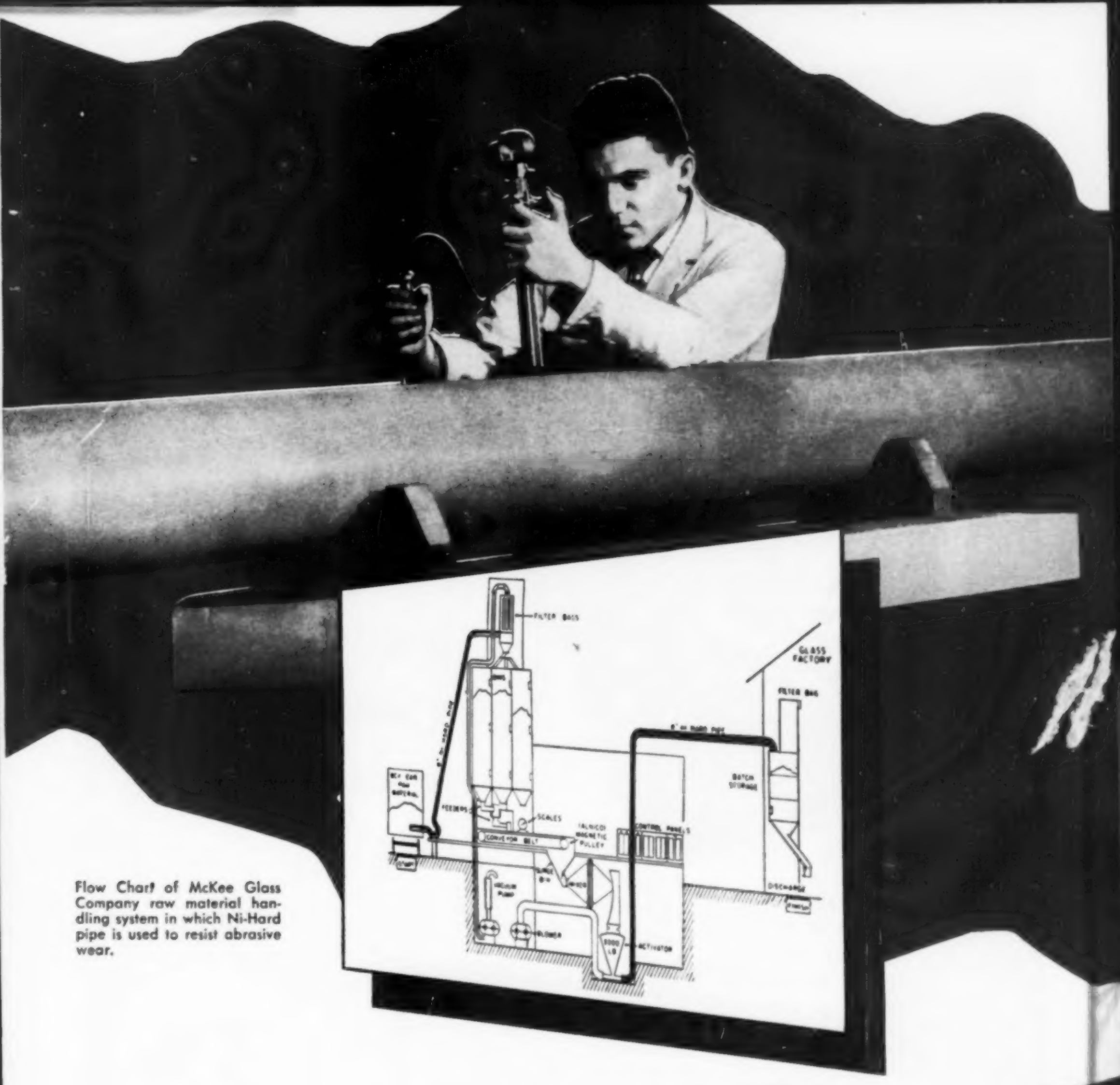
Two years ago when the system was installed steel piping and later, lined steel piping was used. The severe abrasive action coupled with serious discoloration of the glass led to the search for a better conveying material. As a result, Metal Mold centrifugally cast plain end Ni-Hard pipe with a Brinell hardness of 600-650 was installed in the line's most abrasive sections.

The result, as reported by McKee, was more than satisfactory. Contamination was reduced 80%. Ni-Hard resisted abrasion much more effectively, as shown by the chart below . . . thus far, in fact, has carried *ten times the tonnage and the line is still going strong!*

Today, the McKee Glass Company uses Ni-Hard exclusively in its conveying system. Their experience may suggest the answer to *your* abrasion problem.

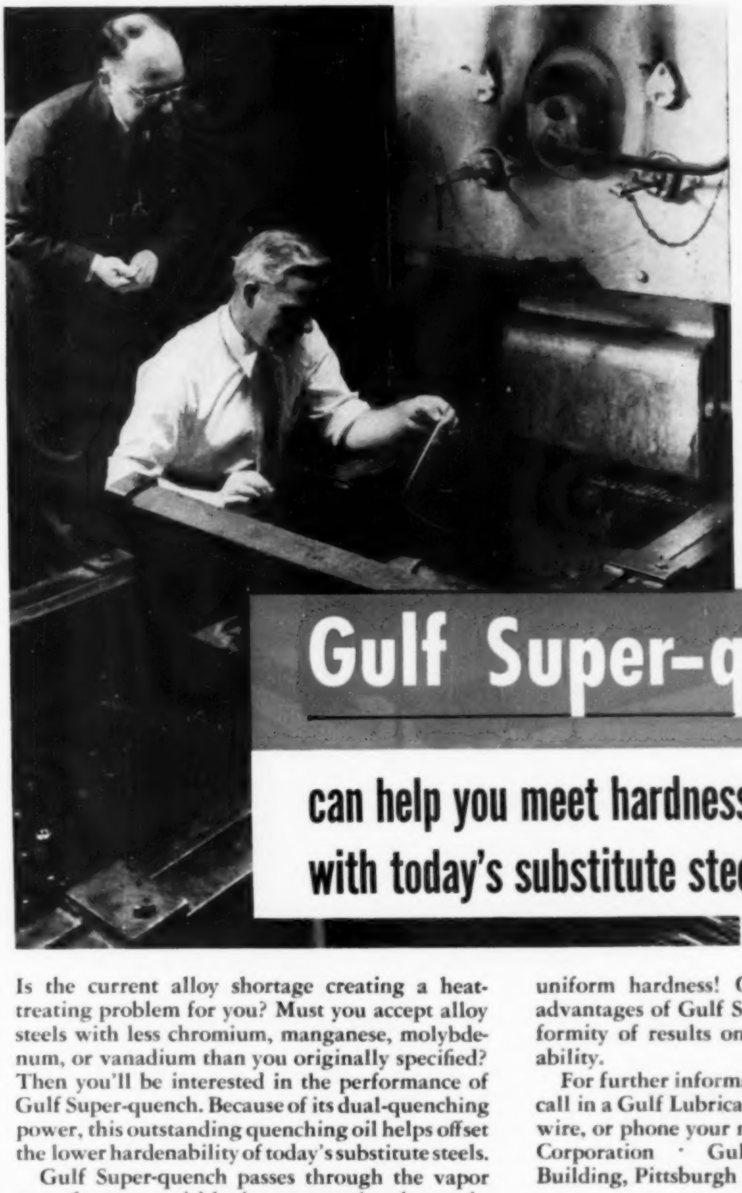


†Nickel-chromium white cast iron.
Ni-Hard is a registered trade name of
The International Nickel Co., Inc.



Flow Chart of McKee Glass Company raw material handling system in which Ni-Hard pipe is used to resist abrasive wear.

MODERN INDUSTRIAL DESIGNERS KNOW..
Bronze Gears Retain Their Physical Properties Under Constant Usage
Bronze gear wheels are a *must* when used with hardened steel worms in speed reducing systems. The bronze gear teeth maintain their correct form due to the regenerating action of the hardened worm.
Only in bronze can be found the unusual combination of plasticity, durability, strength and wear resistance required for this type of service.
Specify—LAVIN NON-FERROUS INGOT—Quality
R. LAVIN & SONS, INC.
Refiners of Brass, Bronze and Aluminum
3426 SOUTH KEDZIE AVENUE · CHICAGO 23, ILLINOIS
REPRESENTATIVES IN PRINCIPAL CITIES




XII
IX
III
VI

Finishing Aluminum

Vitreous Enamels provide abrasion and heat-resistant coatings for aluminum. They adhere well, are easy to apply.

The sequence of operations for applying vitreous enamels on aluminum are: cleaning, spraying, oven drying, fusing the enamel frit at high temperature.

Parts are cleaned by wiping with cloths saturated with solvents or by vapor degreasing. Inhibited alkaline cleaners should be used. The enamel frits are mixed with water or turpentine, sprayed on and oven-dried. Quick drying by oven is important because the free alkali in the enamel mixture will cause surface corrosion if parts are left to air-dry.

The enamel is fused at temperatures from 940 to 1000° F. This heat will partially anneal temper rolled sheet. The heat treatable alloys will be partially heat-treated, but not to a full degree, because quenching is not possible.

Vitreous enamels on aluminum have the advantages of excellent resistance to impact and thermal shock. Certain coatings have exceptional resistance to mild acids.

For complete information on finishing Alcoa Aluminum write to the address below.

Aluminum Die Castings

The difference between average and exceptional die castings is often the kind of design help the supplier offers. Consider Alcoa's qualifications.

Alcoa offers the kind of technical literature and personal design consultation that you would expect from the leader in the aluminum industry and a die-casting supplier of 34 years' experience.

The help of an Alcoa sales-engineer is instantly available through your local Alcoa sales office. He is thoroughly familiar with the methods of applying aluminum die castings to your particular design problems. He will accurately interpret your production problems to the casting experts

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA • 1805M GULF BLDG., PITTSBURGH, PA.

at Alcoa's two modern die-casting plants. Often the simple suggestions that come from the close attention that Alcoa experts give your drawings can result in substantial savings and surprising increases in the performance of the finished product.

For the designer's technical library, Alcoa offers two books: "Designing for Alcoa Die Castings" — a 188-page book which covers all phases of design, machining and finishing. And "Machining Alcoa Aluminum" — a 67-page book which describes tooling, setup and machine speeds for all machining operations. Both books may be obtained through your local Alcoa sales office or by writing direct to the address given below.

Besides standard and special fasteners, Alcoa produces bushings, inserts for plastic and cast products, nozzles, valves, aircraft parts, electrical fittings, couplings, pipe and tube fittings.

Aluminum Fasteners

Alcoa supplements its complete line of standard fasteners with a broad range of special fasteners made to customer specification.

The capacity and versatility of Alcoa's headers, threaders, slotters, screw machines and related secondary equipment permit Alcoa to provide industry with thousands of standard and special fasteners made from aluminum alloys.

Alcoa's 63 years of aluminum experience can be counted on to provide the best obtainable products of this type. Engineering and design assistance are readily obtainable for analysis of your parts to determine where costs can be lowered and quality improved. Special tools and gauges are built in Alcoa's own toolrooms to facilitate production and inspection. And there is capacity in Alcoa's plants for reasonable delivery schedules to manufacturers with authorized production schedules and metal allotments.

ALCOA ALUMINUM ®

ALUMINUM COMPANY OF AMERICA • 1805M GULF BLDG., PITTSBURGH, PA.

Aluminum Extrusions

permit placement of metal where maximum strength is needed... save greatly in material and fabrication costs.

Almost any shape can be produced by Alcoa — hollow, semi-hollow, solid. While cross sections must remain constant throughout the length of the shape, extrusions permit thick sections where stresses are concentrated — thin sections in areas of minor loading. In both metal cost and shop time, extrusions often can save substantially over roll forming or building up an equivalent section.

To help you visualize the almost limitless possibilities of aluminum extrusions, and to suggest ways you can adapt your designs to them, Alcoa has prepared a special booklet that's yours for the asking. Write for "Alcoa Aluminum Extruded Shapes."

Booklet offers basic design help...

- ✓ a discussion of design and production advantages of aluminum extrusions.
- ✓ examples of aluminum extrusions that have increased strength and stiffness because of efficient metal distribution.
- ✓ examples of designs that have been simplified by the use of a single extruded shape to replace expensive built-up assemblies, castings or machined sections.
- ✓ illustrations of the way several extruded shapes can be combined to simplify assembly and reduce costs.
- ✓ suggestions on modifying designs to utilize standard shapes and shapes for which dies are available.

ALCOA ALUMINUM ®

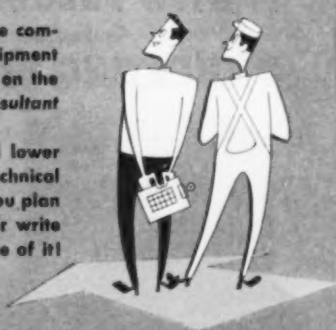
ALUMINUM COMPANY OF AMERICA • 1805M GULF BLDG., PITTSBURGH, PA.

SILVALOY

An interesting example of top brazing efficiency with "*preformed*" rings!

SILVALOY preformed rings are used with utmost efficiency to braze the component parts of this unit for the General Electric Home Laundry Equipment Division. The Silvaloy preformed ring is quickly and easily positioned on the assembly and the complete unit is placed in an induction furnace — *the resultant joint is stronger than the metals joined!*

Silvaloy brazing is successfully helping to increase production and lower costs for thousands of manufacturers throughout the country. Our technical experts are always on call and will be glad to visit your plant to help you plan for best brazing results, lower costs and increased production. Call or write today. This useful service is offered without obligation. Take advantage of it!



SILVALOY SILVER BRAZING ALLOYS ARE SUPPLIED FROM STOCK THROUGH A RELIABLE DISTRIBUTOR IN YOUR AREA

DISTRIBUTED BY:

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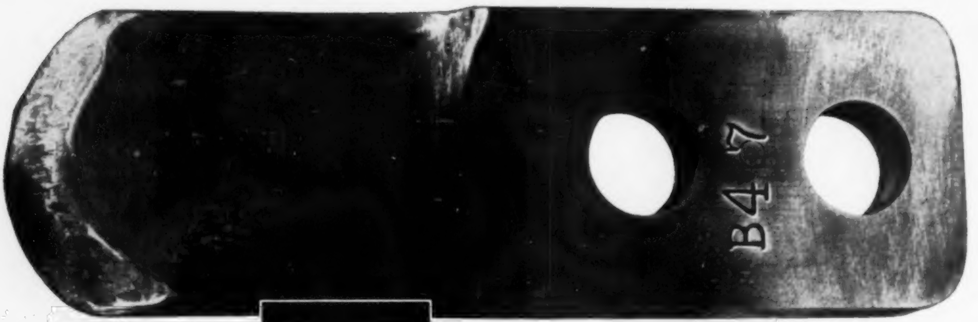


This punch gave double service!

B·47 HOT WORK STEEL

gives you more <u>runs</u> for your money

*. . . anywhere from **1½** to **5** times the Performance!*

This block had double life!

This die lasted 50% longer!

SOME TYPICAL EXAMPLES

B-47 dummy blocks, vs. 9% and 12% tungsten types, extruded more than twice as many brass and copper tubes. B-47 dies outperformed 12% tungsten type 1½ to 1.

B-47 punches, vs. low-carbon 18-4-1 type, hot pierced more than twice as many eyes in steel axes. See top picture.

B-47 die inserts, vs. 9% tungsten types, hot pressed more than twice as many steel side gear forgings. B-47 die inserts, vs. regular insert material, performed better than 5 to 1.

B-47 dummy blocks, vs. 5% tungsten-5% chromium types, extruded twice as many copper and brass tubes and rods. B-47 dies outperformed 12% tungsten-12% chromium type.

B-47 punches, vs. 5% chromium type, hot extrusion forged 1½ times as many automotive steel front axle spindles.

B-47 die inserts, vs. 9% tungsten types, extruded 1½ times as many high alloy steel automotive valves. This is considered a very difficult job for any grade of hot work steel.

SEND NOW

for "Blue Sheet" on Grade B-47

This four-page folder gives technical data on B-47 for brass extrusion dummy block and dies, valve extrusion die inserts, hot punch tools, forging die inserts, press forging dies, and hot work in general. *Write for your copy today.*

ADDRESS DEPT. MP-24

Looking for a better hot work steel? You'll find it in B-47—an improved chromium, tungsten, cobalt, vanadium type whose superiority is established by actual performance runs such as those summarized above. All tests show that B-47 has unusual resistance to shock and abrasion at elevated temperatures.

Developed originally for applications in the copper and brass industry, B-47 has given excellent results on difficult hot work jobs on steel. B-47, when properly heat treated, exhibits a well rounded combination of red hardness, toughness, and resistance to wear and heat checking that makes it a valuable addition to the Allegheny Ludlum group of hot die steels.

Put B-47 to the test. You'll find that it will do any number of severe hot work jobs without washing out or changing size. Get in touch with A-L, today. Let us help you to use B-47.

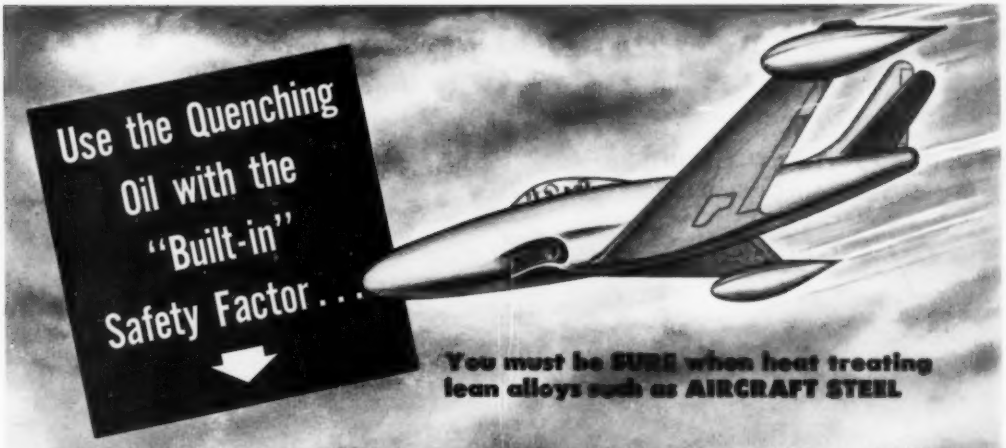
● *Allegheny Ludlum Steel Corporation, Henry W. Oliver Bldg., Pittsburgh 22, Pa.*

For complete <u>MODERN</u> Tooling, call

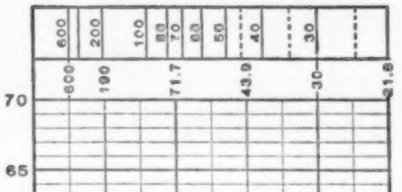
Allegheny Ludlum

A-L FINE TOOL STEELS SINCE 1854

W&D 3530



HOUGHTO-QUENCH "K"



A Jominy comparison of water at 75 F., 100-second mineral oil and Houghto-Quench "K" at 120°F., using AISI 8740 Steel.

Just as steel needs a high safety factor, so does your heat treating procedure. And you get it when you use Houghto-Quench "K", Houghton's brand new treated quenching oil developed specifically to provide speedier quenching of today's lean alloys.

You can be *sure* with Houghto-Quench "K". Its accelerated quenching properties are just what the heat treater must have for steels with hardenability characteristics in the *lower* ranges of the hardenability band.

It gives you that extra measure of safety which government specifications for aircraft steels (MIL-H-6875) demand. It eliminates experiments and costly rejects, because it quenches varying heats with equal dependability. The chart at the left proves the speed of Houghto-Quench "K" compared with water and straight mineral oil quenching.

With today's demands increasing daily for high speed quenching, we have stepped up production of Houghto-Quench "K" to make it more readily available. Write to E. F. Houghton & Co., Philadelphia 33, Pa., for prices and descriptive material.

HOUGHTO-QUENCH "K"
. . . a product of

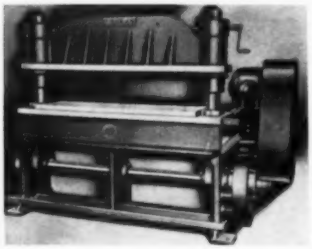
E. F. HOUGHTON & CO.
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .

Engineering Digest

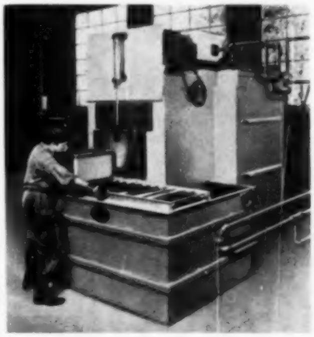
OF NEW PRODUCTS

PRESSES: New twin-column punch presses have been announced by the Wales-Strippit Corp., which may be used for all types of blanking, forming, drawing and bending. Also Wales hole punching and notching equipment is used efficiently on these presses. In addition, a self-contained shearing attachment is available as optional equipment for precision shearing. The cylindrical pair of ram guides are 4 in. in diameter, precision ground, highly polished, and positioned vertically at exactly 90° which reduces possible wearing to a minimum. The actuating mechanism of the ram operates inside the vertical ram posts.



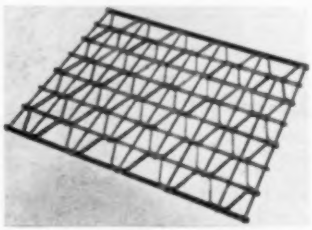
Guide sleeves move up and down on the ram guides. These sleeves are hand scraped, individually fitted, and held to the close tolerance of 0.00025 in. Long press life and accurate alignment are assured by heavy-duty liners in the sleeves which are fully enclosed by a two-way seal that eliminates dirt and chips by wiping the ram posts clean.
For further information circle No. 758 on literature request card on p. 32B

ATMOSPHERE FURNACE: The Dow Furnace Co. announces the recent development and successful operation of a small, pitless, batch-type controlled-atmosphere furnace for production gas cyaniding, gas carburizing, clean hardening and carbon restoration. Called the Model G, the furnace is completely mechanized and self-contained for ease of operation and simplified material handling. It will heat 500 lb. of work from room temperature to 1500°F., in 1 hr., provided the furnace is stabilized at control temperature when the load is introduced. Heating is by four radiant tubes fired with standard Dow burners. A gas generator system of catalytic type is incorporated within the radiant



tubes to supply a gas neutral to medium-carbon steels. An unusual feature of the tube and generator system is that the generator gas can be analyzed before it enters the furnace.
For further information circle No. 759 on literature request card on p. 32B

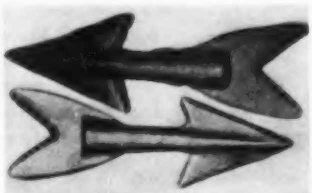
ALLOY GRID: An alloy grid that successfully meets the rigid requirements of the heat treating field has been designed by Rolock engineers. This "Serpentine" grid is very light in weight yet capable of performing with a minimum of distortion for an extremely long service life. Simple in



design and fully articulated with loose tie rods, the grid is connected with longitudinal bars as the principal load-carrying members, spaced with serpentine-like intermediate bars which also serve to maintain their vertical alignment.
For further information circle No. 760 on literature request card on p. 32B

WELDING FLUX: New improved types of flux aimed at cutting costs and improving quality in any fusion welding process on corrosion and heat resistant metals have been announced by Solar Aircraft Co. The company has now developed four types of back-up flux used to weld stainless steel and other high nickel and cobalt alloys. In one recent case, use of Solar flux in the welding of high strength, low alloy steel aircraft engine parts cut rejects 95%, cut materials handling by two-thirds, and boosted welding operator efficiency by 10%. The various fluxes are combinations of compounds used to remove surface oxides and prevent oxidation of parts during the welding cycle, which in turn minimizes chipping, grinding, and finishing. They also control the penetration of the weld by permitting higher welding temperatures without "burn-through".
For further information circle No. 761 on literature request card on p. 32B

BARREL FINISHING COMPOUND: A special-purpose chemical for barrel finishing brass, bronze, copper, gold and silver stampings, castings, machined and drawn parts is offered by Blue Magic Chemical Specialties Co. This compound is recommended for finishing either with or without media,



and with selected nonferrous media for roughing, deburring, cleaning and finishing in a single operation. Recommended quantities are only 4 oz. of compound for finishing runs in a 32 x 30 in. tumbling barrel at high water level. As a cutting compound in deburring operations only 1 to 2 oz. of compound is needed at a low water level in the barrel.
For further information circle No. 762 on literature request card on p. 32B

THICKNESS GAGE: Two new model absorption and backscatter beta gages for sheet materials have been developed by Tracerlab, Inc. A beta gage, in effect, weighs a small area of the moving sheet by means of a beam of radiation. If the density of the material is maintained constant the meter can be calibrated in units of thickness, thus making the gage a sensitive thickness control instrument. Beta gages do not contact the material being gaged, may be installed in any location on the machine, and the meters or recorders may be placed at a distance. Beta gages measure extremely thin mate-

40th anniversary of an organization and a symbol

QUALITY · ZIVCO · **SERVICE**

A symbol of honest and reputable dealing. To our friends both old and new, we extend our most sincere thanks. Their trust and confidence is our most treasured asset.

DIE PRODUCTION MEASURED IN MILES ....

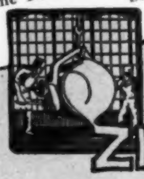
This Roll-Die Set made of **Ziv's Wizard Unbreakable Tool Steel** operates out in the open, in all kinds of weather, at the St. Louis Shipbuilding and Steel Co., the largest inland shipbuilding company in the world. Hot rolled steel channels and sheet stock are serrated in lengths up to 60 ft. To date these tools have chewed through approximately 564 miles of stock or roughly the distance from Cleveland to St. Louis, and there's plenty of mileage left.

BRANCHES

14643 Meyers Road
Detroit 27, Mich.

1617 N. Seventh St.
St. Louis 6, Mo.

3731 W. Highland Blvd.
Milwaukee 8, Wis.



ESTABLISHED 1911

ZIV STEEL & WIRE CO.

High Grade Tool Steel

ZIVCO TRADE MARK

2945 W. Harrison Street - - - - - - - CHICAGO 12, ILL.

BRANCHES

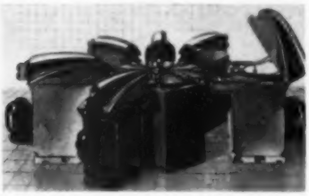
633 Fulton St.
Indianapolis 2, Ind.

1819 Starr Ave.
Toledo 5, Ohio

Eagle River, Mich.

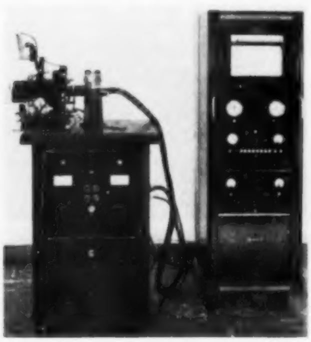
rials impossible to gage by other methods and offer advantages for many installations because they are mounted on one side of the sheet only.
For further information circle No. 763 on literature request card on p. 32B

MICRO-LAP: The Murray-Way Corp. has developed a new automatic, precision polishing process which will be known as Micro-Lap. The new process and equipment were developed especially for the fast, accurate and economical microsurfacing of jet-engine blades and buckets but has a wide range of other applications. The polishing heads are mounted on floor



bases and operate continuously with no pause for indexing. The polishing jaws open automatically to receive and release the workpiece as it makes the cycle. Successively finer grits under flood lubrication accomplish a finish of 3 to 4 rms. in 6 sec.
For further information circle No. 764 on literature request card on p. 32B

FLUORESCENCE ANALYSIS UNIT: The new Norelco fluorescence analysis unit which incorporates many design improvements to facilitate rapid qualitative and quantitative analysis of constituents in metals, alloys, minerals, ores, chemical mixtures and compounds, is now in production at the North American Philips Co. The new unit employs a wide-range vertical goniometer with a sweep radius of 170 mm. instead of the horizontal assembly used on the original model.

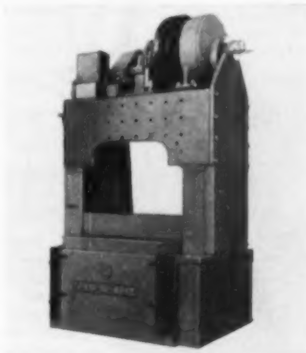


The equipment utilizes a horizontal, water-cooled, oil-insulated X-ray tube. The output of the special volume-sensitive Geiger counter is processed in electronic circuits for the purpose of driving a strip chart recorder or a count register. As distinguished from X-ray diffraction, which gives precise data about atomic structure, fluorescence analysis provides precise quantitative and qualitative data with respect to the elements present. Difficult analyses involving solids, semisolids and liquids can be carried out in much less time than when ordinary chemical methods are employed.
For further information circle No. 765 on literature request card on p. 32B

POTENTIOMETER: A new potentiometer circuit that permits measurements of spans as narrow as 100 microvolts has been developed by Minneapolis-Honeywell Regulator Co. The new instruments can be used wherever accurate measurements of d-c. potentials of the order of microvolts is required. In addition to direct voltage determinations, as encountered in many scientific, technical and electronic investigations, the instruments are useful (with appropriate primary measuring elements) for the precise measurement of differential temperatures, and the accurate determination of slight variations in the temperatures of small objects through the use of radiation pyrometry.
For further information circle No. 766 on literature request card on p. 32B

ATMOSPHERE GENERATOR: The Hevi Duty Type M-5724-S "Atmo-Gen" atmosphere generators are used to provide atmospheres for the following heat treating operations: clean nondecarburized hardening, dry cyaniding or carbonitriding, carburizing (carrier gas), copper and silver brazing, nitriding, sintering and bright annealing. The unit delivers 150 cu. ft. of atmosphere per hr.
For further information circle No. 767 on literature request card on p. 32B

WELDING PRESS: Development of a gap-frame press, in cooperation with a major automotive manufacturer, for use with welding fixtures in the mass production of spot welded assemblies, is announced by **E. W. Bliss Co.** The gap-style frame permits conveyorized feeding from side to side,



which facilitates easy access to the work by operators. Work is accessible from either front or back of the press. Parts to be welded are laid on the lower "die", which contains welding tips, and moved up into contact with the fixed welding tips attached to the upper part of the press.
For further information circle No. 768 on literature request card on p. 32B

WELDING MACHINE: A new heavy-duty d-c. welding machine has been put on the market by the A. O. Smith Corp. The machine is designed for all industrial uses where d-c. welding is required. Extensive field testing has shown the new unit to be free of stack failure. This is accomplished by directing a high-velocity downdraft of cool air over the rectifier

stacks before passing this air through other parts of the machine. The welder is available in 200, 300 and 400-amp. ratings.

For further information circle No. 769 on literature request card on p. 32B

SUBZERO CABINET: A new low-temperature cabinet, introduced by the Brewer-Titchener Corp. features subzero temperatures as low as −40° F. It can be used for rivet cooling, shrink fit assembly, size stabilization in metal, storing punched and formed aluminum alloy parts, applying sub-

zero cooled compressed air to metal cutting tools and treating hardened steels. The unit is 40 in. long by 36 in. wide. It has 2½ cu. ft. of refrigerated storage space.

For further information circle No. 770 on literature request card on p. 32B

STRAIGHTENER: The advantages of quick and easy setup inherent in the overhung roll type of shape straightener, and the desirable and exceptional control of bending stresses possible in a straightener with variable centers, have been combined in a new shape

straightening machine developed by the Medart Co. Variable-center rolls permit extreme versatility in the adjustment of bending spans necessary in the handling of a virtually unlimited range of shapes and sizes. In addition, the adjustment of bending spans, possible with movable roll housings, prevents the overloading of bearings and assures greater accuracy in straightening operations.

For further information circle No. 771 on literature request card on p. 32B

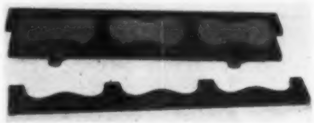
CUTTING FLUID: A new lubricant-coolant solution, Cool-O-Lube, offers increased effectiveness by both free flowing and compressed air application. When applied by Pur-o-luber equipment, the effectiveness of the solution carried by the compressed air stream is many times greater than free-flowing coolants, or its own results when applied by conventional methods. This new solution is sold by Air Conversion Research Corp. as a concentrate and is diluted 1 part solution to 9 parts of water.

For further information circle No. 772 on literature request card on p. 32B

STAINLESS COATING: A new stainless steel coating which may be applied to any metal has been developed by Steelcote Mfg. Co. It gives protection against rust, corrosion and other types of deterioration caused by salt air and water, industrial atmospheres, alkalies, oils, greases, most strong acids, heat, cold and sunlight. Applied by brush or spray gun, it dries in 30 to 60 min. and the part is ready for use in 3 to 4 hr. Cost per square foot is low.

For further information circle No. 773 on literature request card on p. 32B

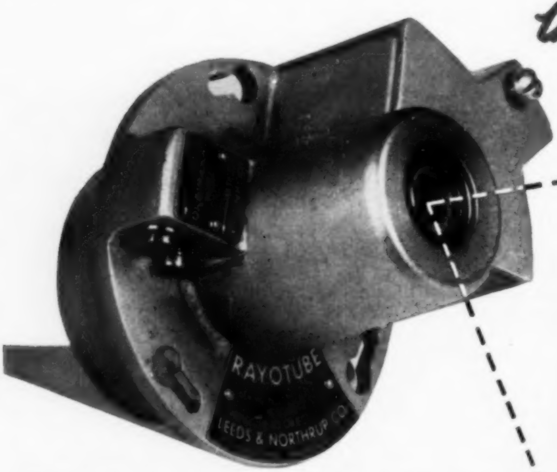
SHELL MOLDING: The variables of sand, binder, binder ratio and curing cycle all affect the strength of the mold shell. In order to make an intelligent selection and maintain control, it is necessary to measure this strength. This may be done conveniently and accurately by means of the No. 362 shell molding tensile



accessory which is now available from the Harry W. Dietert Co. A core box is provided which makes three tensile cores ¼ in. thick, and may be inserted in the laboratory core oven for curing. Cores are tested by means of the No. 610 core tensile accessory.

For further information circle No. 774 on literature request card on p. 32B

Can this new Rayotube mean better control of temperature in your plant?



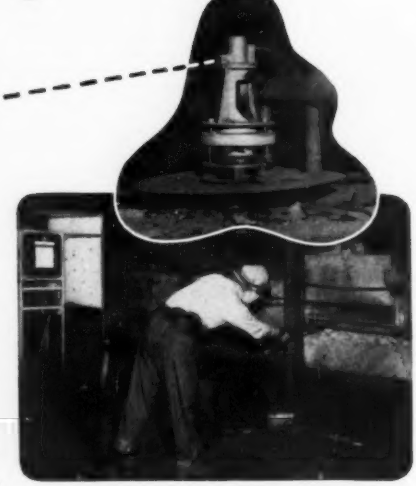
BUILT to detect temperatures for either Speedomax or Micromax Controllers, this new Rayotube No. 8890 has three features which help to improve the accuracy of control action.

1. The water jacket often needed for earlier Rayotubes is seldom required for this one because accuracy is not affected by ambient temperatures unless the head housing itself (shown above) exceeds 350 F. Omitting the jacket greatly simplifies installation and saves both water and maintenance due to water lines.

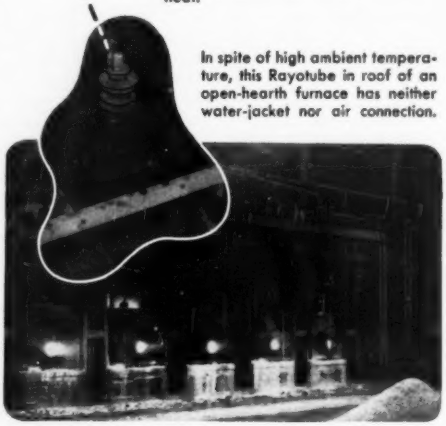
2. Overheating the Rayotube head to as high as 500 F does no harm; the accuracy decreases above 350, but returns fully as temperature drops. Thus, a few minutes' glare from an open furnace door does not affect the instrument's usefulness.

3. New, quick-sighting optical system for aiming the Rayotube at area of important temperature is especially helpful when aiming down an open-end tube to measure directly the surface temperature of parts being heated.

Catalog N-33B describes all Rayotubes as well as Speedomax and Micromax Pyrometers; we also can send description of this Rayotube only. Kindly address either our nearest office, or 4927 Stenton Avenue, Philadelphia 44, Pa.



In Henry Disston & Sons, Inc. plant, Rayotube in slab furnace roof needs no water-jacket against high ambient heat.



In spite of high ambient temperature, this Rayotube in roof of an open-hearth furnace has neither water-jacket nor air connection.

Jrl Ad NS3(2)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LN LEEDS & NORTHRUP CO.

What's New

IN MANUFACTURERS' LITERATURE

775. Air Velocity Control
Bulletin 2448-G describing portable instrument for measurement of air velocity thru grills, furnaces and in the open. *Illinois Testing Laboratories.*

776. Alloy Brazing
New bulletin 20 covers silver alloy brazing with Easy-Flo and Silfos. Tells where and how to use these alloys to the best advantage. Shows many interesting applications; describes fast brazing techniques. *Handy & Harman.*

777. Alloy Steels
New 16-page, pocket-size booklet contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

778. Alloys, Heat Resisting
"Thermalloy 30" gives property data for 21% Cr, 9% Ni heat resistant alloy. *Electro-Alloys Div.*

779. Aluminum
"Alcoa Aluminum Impact Extrusions", giving information on impact extrusion process and service. Shows range of shapes for engineering. *Aluminum Co. of America.*

780. Aluminum Welding
New control system that extends electrode life for spot welding aluminum, fully described in "Technical Advisor No. 15". *Reynolds Metals Co.*

781. Anti-Carburizing Paint
Descriptive literature is available on paint which prevents carburizing or hardening of certain spots on steel parts. *Case Hardening Service Co.*

782. Atmosphere Generators
Bulletin on atmosphere generator for small-capacity furnaces. Flow diagram, specifications, applications. *Hevi Duty Electric Co.*

783. Belts, Wire
Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

784. Bimetal Elements
64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

785. Bottom Boards, Magnesium
Complete information and price schedule on magnesium bottom boards for maintaining high quality castings and mold stability. *Christiansen Corp.*

786. Brass and Bronze
8-page, illustrated booklet on control methods as applied to brass and brass rod, forgings, die castings and welding. *Titan Metal Mfg. Co.*

787. Brazing, Silver
48-page, pocket-size manual on all aspects of silver brazing applications and problems. *The American Platinum Works.*

788. Burners
14-page, illustrated booklet displays full line of long flame burners for gas, for oil and for gas and oil. Complete diagrams and descriptions. *Bloom Engineering Co., Inc.*

789. Carbon Analysis
Bulletin 319 describes the Combustron, electronic induction heater in two or one-tube model for flexibility in analysis of low to high carbon content in alloy steel, cast iron and stainless steel. *Burrell Corp.*

790. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup Co.*

791. Cast Iron
48-page book, profusely illustrated, showing a wide range of light and medium castings produced in gray, alloyed and inoculated irons. *Hamilton Foundry & Machine Co.*

792. Cast Iron
4-page booklet providing case histories of unusual applications of Meehanite castings in various industries. *Meehanite Metal Corp.*

793. Cast Iron Inoculant
8-page folder describing an inoculant, metallurgically designed to improve machinability, add toughness, and increase resistance to wear. *International Nickel Co., Inc.*

794. Cast Monel
New bulletin concerning production of cast Monel and wide range of physical and mechanical properties obtainable. *Cooper Alloy Foundry Co.*

795. Castings, Heat Resistant
4-page bulletin describes heat resistant castings produced in designs for a wide variety of applications, including conveyors, roller hearths, trays, and radiation tube assemblies. *Standard Alloy Co.*

796. Castings, Wear Resistant
New descriptive folder gives interesting facts on Colmonoy hard-facing alloys, developed to combat different types of wear: abrasion, corrosion, impact, etc. Made in various forms to suit the methods of application. *Wall Colmonoy Corp.*

797. Cleaner
A descriptive product data sheet describes 313-A, a special acid phosphate cleaner developed for preparation of metal surfaces for painting, lacquering or japanning. *E. F. Houghton & Co.*

798. Cleaner
Bulletin 74-15 gives data on all-electric steam detergent cleaning. Pressures to 200 psi. *Livingstone Engineering Co.*

799. Cleaners
Descriptive folder features emulsion cleaners designed to remove both oil-soluble and water-soluble soils from any metal or alloy without attacking the base metal or paint finishes. *Detrex Corp.*

800. Cleaners
Bulletins on Virgo descaling salt and Virgo molten cleaners. What they are, how they work, their advantages and how they fit into your operations. *Hooker Electrochemical Co.*

801. Cleaning
Data on Aja-Lif equipment for removal of buffing compounds, chip removal, quenching and other cleaning operations. *Magnus Chemical Co.*

802. Cleaning and Finishing
Attractive 12-page, well-illustrated catalog A-652 gives the complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines operating in large metalworking plants. *R. C. Mahon Co.*

803. Coatings
Information on Bonderite, nonmetallic coating which is resistant to corrosion and a good paint base. *Parker Rust Proof Co.*

804. Coatings and Packaging
New 43-page working data file provides valuable guide to better preservation and packaging with three sections on coatings, melting equipment and processing procedures for "hot dip" packaging. *Seal-Peel, Inc.*

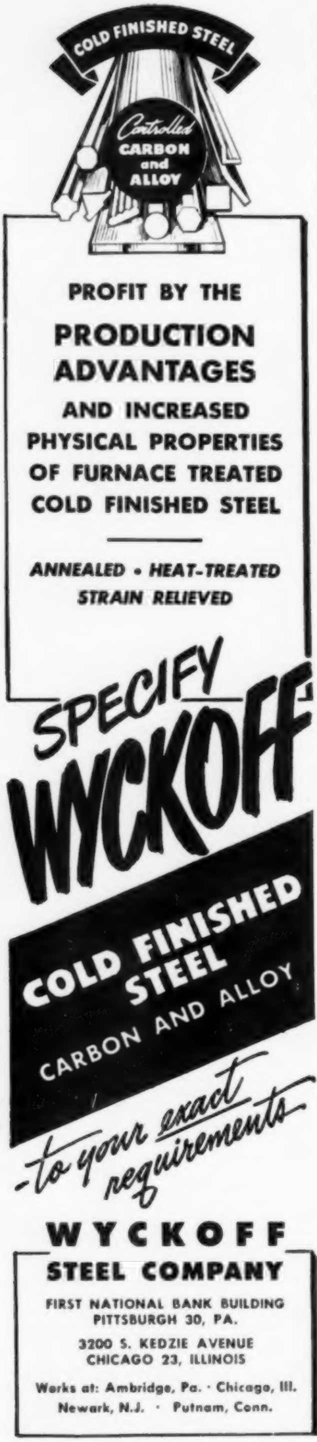
805. Coatings, Metal
Explanations of high-vacuum evaporation of metals and other solids set forth in new 12-page booklet. *Distillation Products, Inc.*

806. Contact Wheels
New type of rubber contact wheel which adds 50% more life to abrasive belts is described in folder. *Carborundum Co.*

807. Controls
Catalog No. 51-1 gives full data on controls for annealing furnaces including ElectroniK potentiometer controls, Air-O-Line pressure controls, pyrometer and switch for spot temperature checks and flow meter for fuel cost accounting. *Minneapolis-Honeywell Regulator Co.*

808. Copper Alloy Tubes
An extensively illustrated 32-page brochure deals with causes of corrosion and means of combating them as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

809. Copper Alloys
New 44-page booklet on application and installation of condenser and heat exchanger tubes, also plates for tube sheets, heads and baffles. *The American Brass Co.*



810. Corrosion Data
Wall chart of useful corrosion resistance information for several analyses of stainless steel tubing and pipe in contact with various corrodents. Reverse side contains mechanical data on tubing. *Carpenter Steel Co.*

811. Cupola Charging
Second of a series of booklets on better foundry operation, entitled "Tips on Improving Cupola Charging", contains valuable information on obtaining a smoother flow of materials from freight cars to cupolas. *Whiting Corp.*

812. Cutting Oils
4-page folder on control of soluble oil coolants, blending and reclaiming. *Bowser, Inc.*

813. Cutting Oils
Shop notebook giving important facts on right cutting fluid for any machining operation. *D. A. Stuart Oil Co.*

814. Cut-Wire Shot
Economies and characteristics of cleaning and peening with cut-wire shot are described in a 4-page folder. *Cleveland Metal Abrasive Co.*

815. Die Steel
New literature available on Bethlehem Cold-Headed Die Steel for high production in forging bolts, rivets, screws, and other products at high speed. *Bethlehem Steel Co.*

816. Die Steel
Booklet, "Die Steels for Hot Work", helps in selection of best grade for your particular job. *Vanadium-Alloys Steel Co.*

817. Drawing Compounds
Folder describes new type of lubricant for cold forming and drawing of stainless steel, both austenitic and ferritic. *Hangsterfer's Laboratories, Inc.*

818. Fabrication
Illustrated folder describes facilities for mass production of defense prime contract and subcontract work. *Charles T. Brandt, Inc.*

819. Fasteners
Descriptive and illustrative 17-page bulletin on types, sizes and applications for rivets and riveting tools. Many useful engineering charts. *B. F. Goodrich Co.*

820. Fasteners
Three-color, 56-page price list and stock book for complete line of fastenings in brass, bronze, copper, Monel, aluminum, stainless steel. *H. M. Harper Co.*

821. Fasteners
Complete file contains illustrations and engineering descriptions of fasteners and fittings for resistance welding, adjusting screws and other products. *Ohio Nut & Bolt Co.*

822. Ferro-Alloys
"Electromet Products and Service" gives helpful information about the use of ferro-vanadium and other alloying metals. *Electro Metallurgical Co.*

823. Flow Meters
Catalog C-12 gives complete line of meters and accessories for measuring pressure, vacuum and differential pressure of liquids and gases. *Meriam Instrument Co.*

824. Forging Machines
Bulletins describing Acme XN Forging Machines, featuring the exclusive toggle link construction. *Hill-Acme Co.*

825. Forging Steel
Bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. *Timken Roller Bearing Co.*

826. Forgings
A new 16-page illustrated pamphlet follows a forging from the electric furnace through forge shop, heat treating, machining and inspection. *National Forge and Ordnance Co.*

827. Forming
Special bulletin of metal spinning, stamping and fabricating facilities. *C. A. Dahlin Co.*

828. Fuel-Air Ratio Control
Metered control of fuel-air ratio in single and dual-fuel metallurgical furnaces is discussed in Instrumentation Data Sheet 4.3-4. *Minneapolis-Honeywell Regulator Co.*

829. Furnace Controls
Instruments and controls for heat treating furnaces are described in bulletin 49-750. *Hays Corp.*

830. Furnaces
Catalog 112 features new heat treating furnaces and atmosphere charts. *C. I. Hayes, Inc.*

831. Furnaces
High temperature furnaces for temperatures up to 2000°F are described in leaflet. *Carl-Mayer Corp.*

832. Furnaces
Eight sizes in gas or electric models as well as conveyorized and batch or pot-type furnaces in bulletin 84P. *Despatch Oven Co.*

833. Furnaces
6-page folder describes 18 typical installations of gas-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

834. Furnaces
Production electric heat treating furnaces are described in Bulletin 1051. Types include those for continuous brazing and sintering, bright annealing, forging and general heat treating. *Harper Electric Furnace Corp.*

835. Furnaces
Bulletin HD-850 describes new shaker hearth furnace used for bright carburizing, bright dry cyaniding or bright hardening of small parts in processing up to 150 lbs. per hour. *Hevi Duty Electric Co.*

836. Furnaces
Illustrated bulletin available with complete description of new controlled atmosphere furnace. *Industrial Heating E uipment Co.*

837. Furnaces
Booklet containing attractive four-color illustrations displays complete line of furnaces. *Loftus Engineering Corp.*

838. Furnaces
Literature describing the use of Marshall tubular furnaces for constant and uniform temperature, furnished in types suitable to your needs. Also radial brackets in stationary and compensating types. *Marshall Products Co.*

839. Furnaces
New illustrated bulletin SC-152 presents heat treating furnaces for the aircraft industry. Conveniently divided into sections on basic aircraft components: steel tubing, aluminum and light metal assemblies, jet and reciprocating engine parts, propeller blades and miscellaneous aluminum forgings. *Surface Combustion Corp.*

840. Gas Analysis
Theory of gas analysis, procedures involved in various analyses and instructions on maintaining and operating equipment are discussed in 60-page manual. *Fisher Scientific Co.*

841. Gas Producers
Bulletin 1-10 supplies technical information on inert gas generators and data on reducing inert gas costs. *C. M. Kemp Mfg. Co.*

842. Gas Sampling
16-page bulletin describing oxygen recorder and applications in sampling and analysis of atmospheres. Instrument based on paramagnetic properties of oxygen. *The Hays Corp.*

843. Hardness Tester
Bulletin F-1689-1 tells of the Impressor, hardness tester for aluminum, copper, brass, bronze and plastics. *Barber-Colman Co.*

844. Hardness Tester
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, outlining experiences in various fields. *Wilson Mechanical Instrument Co.*

845. Heat Treating
Booklet describes complete diversified facilities for steel, aluminum and magnesium heat treating. *Pearson Industrial Steel Treating Co.*

846. Heat Treating
"Surface Hardening of Stainless Steel", illustrated booklet, is available on request. *Lindberg Steel Treating Co.*

847. Heat Treating
4-page technical bulletin explains how maximum hardness and strength of aircraft and other steels can be developed to meet U.S. Gov. Spec. MIL-H6875 thru use of extra high speed quenching oils. *E. F. Houghton & Co.*

848. Heat Treating
Bulletin 120 tells how Niagara Aero Heat Exchangers provide better heat control in quenching bath, thus protecting physical properties and saving on water and piping equipment. *Niagara Blower Co.*

849. Heat Treating Atmospheres
Attractive 7-page brochure investigates background, reviews effects of various gases on steel, analyses composition and uses. *Surface Combustion Corp.*

850. Heat Treating Baskets
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*

851. Heat Treating Controls
Bulletin PB1237 tells of free-vane electronic pyrometer controllers for automatic control of furnaces, ovens and salt pots. *Bristol Co.*

852. Heat Treating Fixtures
Information on complete line of standard carburizing carriers that will handle odd-shaped parts of every type thru carburizing and quenching to finishing. *Pressed Steel Co.*

853. Heat Treating Fixtures
New catalog No. B-8 contains descriptions and photographs of 75 custom-built fabricated alloy heat treating accessories. *Rolock, Inc.*

854. Heat Treating Furnaces
Bulletin SC-153, illustrated in color, describes the fuel-fired batch and continuous furnaces used in production of small caliber ammunition. Back page contains handy reference table showing relation of heat treat furnace equipment to consecutive steps in production. *Surface Combustion Corp.*

855. Heat Treating Furnaces
Illustrated literature describes newest developments in gas and electric heat treating furnaces. *Westinghouse Electric Corp.*

856. Heat Treating Guide
Chart guide constructed on slide-rule principle for simplified hardening and drawing of tool steels. *The Carpenter Steel Co.*

857. Heating Elements
Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

858. Heating for Brazing and Annealing
8-page, illustrated bulletin on high speed heating equipment for brazing, flame annealing, flame hardening, selective heating, and heating for forming. *Gas Appliance Service, Inc.*

859. Helical Springs
2-pager on how to obtain economical assortment of 100 beryllium copper compression springs for development work. *Instrument Specialties Co., Inc.*

860. High Speed Steels
New booklet, "Why Desegatized", shows how these hi-carbon hi-chrome steels help to cut production costs with thorough carbide distribution providing extra toughness and strength. *Latrobe Electric Steel Co.*

861. High Temperature
"Inco High Temperature Work Sheet" provides valuable information and suggestions for solving high temperature problems in design and production. *International Nickel Co.*

862. Induction Heater
Illustrated bulletin on low-frequency (60 cycle) induction heating furnace. Fully descriptive with applications. *Magnethermic Corp.*

863. Induction Heating
New 12-page, two-color bulletin on equipment for induction heating. Describes components and requirements for hardening, brazing, and annealing at 1000, 3000, and 10,000 cycles. *General Electric Co.*

864. Induction Heating
6-page, illustrated folder describes high frequency induction heating as exemplified by new high frequency induction furnace. *Laboratory Equipment Corp.*

865. Induction Heating
Illustrated bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Engineering Corp.*

866. Induction Heating
12-page, illustrated booklet giving 15 case histories of hardening, joining and annealing applications of induction heat. *Westinghouse Electric Corp.*

867. Industrial Planning
New book 127 tells how you can share in "round-table" discussion of planning expansio remodeling or modernization of your plant. *Co tinental Industrial Engineers, Inc.*

868. Instruments
Bulletin W1823 tells of controlling, recordin and telemetering instruments. *Bristol Co.*

869. Insulation, Block
New 4-page folder on Superex block insulati tells economical advantages and lists outstandi properties by means of conductivity and heat lo graphs and recommended thickness table. *John Manville.*

870. Load Testing
Bulletin 325 describes new Type P SR-4 tensi load cells based on SR-4 bonded resistance wi strain gages for load measurement. Gives spec fications for load cells of four capacities betwe 10,000 and 100,000 pounds. *Baldwin-Lim Hamilton Corp.*

871. Lubricant
New bulletin 426-B describes how colloid graphite can solve your lubrication problems metal-forming operations at temperatures fro below zero up to 5000°F. *Acheson Colloids Cor*

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Folder lists rust preventives, lubricants, meta working aids, cutting oils meeting Governme specifications. *E. F. Houghton & Co.*

873. Magnesium
42-page booklet on processing and properties wrought forms of magnesium. Includes 31 tabl *White Metal Rolling & Stamping Corp.*

874. Magnesium Die Castings
Book, "How Magnesium Pays", gives ca studies of the economical uses of magnesium in wide range of products. *Dow Chemical Co.*

875. Metal Analysis
New brochure describes the operation of t ARL Production, Control Quantometer which fu nishes direct-reading, pen-and-ink records of quant tative spectrochemical analyses with extra copi quickly and accurately. Up to 20 chemical el ments measured simultaneously. *Applied R search Labs.*

876. Metal Statistics
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877. Metallizing
Current issue of the Metco News (v. 5, No. describes and illustrates how you can stretch yo "Maintenance and Operating Supplies" dolla with metallizing. *Metallizing Engineering Co., In*

878. Metallizing Process
New 20-page bulletin on the Mogul metallizi gun is fully illustrated and tells how this proce aids in fighting corrosion, rebuilding worn part and reclaiming mis-machined castings. *Meta lizing Co. of America.*

879. Metallograph
12-page catalog describes this completely ne all-in-one desk-type unit for metallographic wor *American Optical Co.*

880. Metallograph
New research Metallograph, described in catal E-240, furnishes four different accurate images same sample for complete identification with brig field, dark field or polarized light. *Bausch & Lon Optical Co.*

881. Microhardness Tester
Bulletin describes the Kentron microhardne tester. *Kent Cliff Laboratories.*

882. Microcasting
New color-illustrated folder, "Microcast Ca Histories", describes microcasting applications f both industrial and defense requirements. *Austen Laboratories, Inc.*

883. Micrographic Equipment
6-page bulletin on a universal camera microsco giving plate magnifications from 4 to 3000 Full details on optics and accessories include *Opplem Co.*

884. Nickel Alloys
"Pickling Equipment for Severe Corrosive Co dition" is a new booklet describing the successf use of nickel-base alloys in this applicatio *Haynes Stellite Co.*

885. Nickel Cast Iron
Bulletin describes eight types of Ni-Resist, giv applications and comparative service data in ma industrial fields. *International Nickel Co., I*

886. Nickel Silver
Paper dealing with detailed description of prop foundry procedure for production of sound castin from nickel silver. Also specification informatio *R. Lavin & Sons, Inc.*

867. Industrial Planning
New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

868. Instruments
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887. Ovens
18 standard sizes of furnaces and ovens, oil, gas or electric; in batch or conveyor type for rapid, uniform heating in controlled temperature and atmosphere, described in bulletin 413. *W. S. Rockwell Co.*

888. Photography
Book entitled "Functional Photography in Industry" describes processes and techniques applicable to a wide range of endeavor. *Eastman Kodak Co.*

889. Plating Barrels
4-page folder illustrates and describes the Daniels Plating Barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

890. Polishing
12-page booklet describing modern techniques of industrial polishing and buffing as related to the varied buffs, polishes and plating supplies. *Schaffner Mfg. Co.*

891. Potentiometer, Portable
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

892. Precision Casting
4-page bulletin on precision investment casting in relation to product design. *Adapti Co.*

893. Precision Casting
4-page folder on cost reduction through investment castings. *Casting Engineers, Inc.*

894. Precision Casting
12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields included. *Alexander Saunders & Co.*

895. Precision Castings
8-page, well-illustrated brochure with informative engineering data on precision castings produced by the Mercast process. *Alloy Precision Castings Co.*

896. Presses
Press owner's manual contains complete operating and maintenance instruction for latest design straight-side double crank presses. *E. W. Bliss Co.*

897. Presses, Bending
Steelweld presses for bending, forming, blanking, drawing and multipunching operations are described in catalog No. 2010. *Cleveland Crane & Engineering Co.*

898. Presses, Punch
Catalog TC describes line of twin-column punch presses. *Wales-Strippit Corp.*

899. Protective Chemicals
Quick reference list of rust proofing, paint-bonding and metal protective chemicals is intended for all fabricators of steel, zinc and aluminum products. *American Chemical Paint Co.*

900. Pyrometer
New circular gives complete information on Xactemp pyrometers. New Type LT-840 and all accessories are illustrated and described. *Claud S. Gordon Co.*

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901. Pyrometer
Bulletin No. GEC-713 contains information on new electric-type pyrometer. *General Electric Co.*

902. Pyrometers
Two portable models, suitable for plant and laboratory, are described in bulletin PPY-1. *Wheelco Instruments Co.*

903. Quenching Additive
New quenching additive described in "Quenzine Story" along with other heat treating compounds. *Aldridge Industrial Oils, Inc.*

904. Quenching Oil
Solution to difficult quench oil purification problems discussed in new bulletin. Also contains detailed operation of M-10-A purifier. *Honan-Crane Corp.*

905. Quenching Oil
New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

906. Recorder
Bulletin CL-1 describes the Wheelco Capaciline with "straight-line" temperature control for use on any kind of heating equipment such as ovens, furnaces, kilns, etc. Available in self-contained unit or as built-in feature of the Capacilog. *Wheelco Instruments Co.*

907. Refractories
New 11-page bulletin on castable refractories containing product descriptions, applications, and charts for applications. Profusely illustrated. *Laclede-Christy Co.*

908. Refractories
Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

909. Refractories
Complete details on refractory cements for every nonferrous melting operation are available in catalog 863. *Norton Co.*

910. Refractory Coating
Descriptive 4-page folder discusses refractory coating made from combination of ceramic and metallic materials. *Williston & Co.*

911. Rolling Mill Equipment
Illustrated 50-page catalog for rolling mills and accessories. Also numerous engineering tables. *E. W. Bliss Co.*

912. Rolling Mills
42-page, illustrated book on development of the continuous strip mill and other equipment for processing ferrous and nonferrous metals. *United Engineering and Foundry Co.*

913. Rust Preventive
New "How" book shows how slushing and degreasing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts. *Nox-Rust Chemical Corp.*

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918. Saws and Saw Blades
Extensive new catalog covering complete line of hand and power hack-saw blades, metal-cutting band saws, band knives and other tools. *Capewell Mfg. Co.*

919. Spectrophotometer
Bulletin B-211 illustrates junior-size spectrophotometer for identifying and measuring solution constituents in analytical or production laboratories. *Harshaw Chemical Co.*

920. Stainless Steel
120-page reference book, cloth bound, on properties, selection, treatment, and fabrication of stainless steels. Wrought forms and castings; high and low temperature properties. Many tables. *Allegheny Ludlum Steel Corp.*

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940. Tool Steels
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941. Tools, Stellite
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945. Ultrasonic Testing
Commercial services using reflectoscope and reflectogage are described in bulletin 50-105. *Sperry Products, Inc.*

946. Vacuum Impregnation
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4-page folder giving specifications and description of press for production of wax patterns for precision casting. *Alexander Saunders & Co.*

949. Welding
"1951 Data File of Defense and Maintenance—Conservation Welding Problems". Over 100 pages of illustrated technical data. *Eutectic Welding Alloys Corp.*

950. Welding Electrodes
New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low-alloy, low-hydrogen electrodes. *Arcos Corp.*

951. Welding Electrodes
19-page booklet, by three welding specialists, summarizes results obtained with commercially available alloy steel rods in arc welding of high-strength ferritic steels. *International Nickel Co., Inc.*

952. Welding Equipment
Cadweld process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

953. Welding Equipment
Welder's crayons for permanent markings on metal surfaces are described in folder. *Wm. Korn, Inc.*

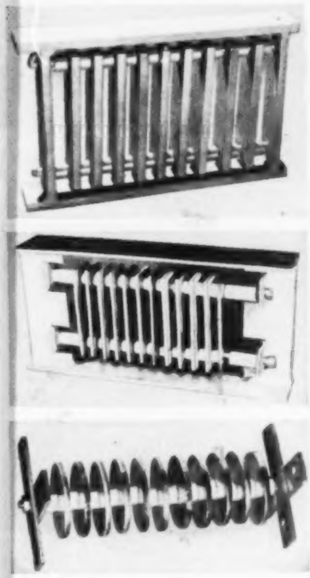
954. Welding, Nickel
New 44-page booklet on fusion welding of nickel and high nickel alloys. Illustrated and containing more than 30 tables. Both electric arc welding and gas welding. *International Nickel Co., Inc.*

955. Welding, Oxy-Acetylene
16-page, illustrated booklet traces the history of the oxy-acetylene flame and explains how industry is using it today in cutting, welding, and heating operations. Many specialized jobs briefly described, such as hard-facing, flame-softening, flame-hardening, powder-cutting and steel-conditioning. *Linde Air Products Co.*

956. Welding Rods
Publication B-13, "Anaconda Welding Rods and Procedures", suggests applications and procedures for production and repair welding, and for building up worn surfaces with bronze rods. Specifications and other tabular data on copper and copper alloy welding rods. *American Brass Co.*

957. Wire Cloth
New manual entitled "Engineers Manual of Wire Cloth Strainer Design" describes selection of the grade of wire cloth and type of metal. *Michigan Wire Cloth Co.*

958. Zinc Plating
Newly revised bulletin on the S-B process for producing zinc deposits satin bright to bright in color, and particularly receptive to conversion coatings such as Lusteron, Cronak, Iridite and Anozinc. *Hanson-VanWinkle-Munning Co.*



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949. Welding
"1951 Data File of Defense and Maintenance—Conservation Welding Problems". Over 100 pages of illustrated technical data. *Eutectic Welding Alloys Corp.*

950. Welding Electrodes
New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low-alloy, low-hydrogen electrodes. *Arcos Corp.*

951. Welding Electrodes
19-page booklet, by three welding specialists, summarizes results obtained with commercially available alloy steel rods in arc welding of high-strength ferritic steels. *International Nickel Co., Inc.*

952. Welding Equipment
Cadweld process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

953. Welding Equipment
Welder's crayons for permanent markings on metal surfaces are described in folder. *Wm. Korn, Inc.*

954. Welding, Nickel
New 44-page booklet on fusion welding of nickel and high nickel alloys. Illustrated and containing more than 30 tables. Both electric arc welding and gas welding. *International Nickel Co., Inc.*

955. Welding, Oxy-Acetylene
16-page, illustrated booklet traces the history of the oxy-acetylene flame and explains how industry is using it today in cutting, welding, and heating operations. Many specialized jobs briefly described, such as hard-facing, flame-softening, flame-hardening, powder-cutting and steel-conditioning. *Linde Air Products Co.*

956. Welding Rods
Publication B-13, "Anaconda Welding Rods and Procedures", suggests applications and procedures for production and repair welding, and for building up worn surfaces with bronze rods. Specifications and other tabular data on copper and copper alloy welding rods. *American Brass Co.*

957. Wire Cloth
New manual entitled "Engineers Manual of Wire Cloth Strainer Design" describes selection of the grade of wire cloth and type of metal. *Michigan Wire Cloth Co.*

958. Zinc Plating
Newly revised bulletin on the S-B process for producing zinc deposits satin bright to bright in color, and particularly receptive to conversion coatings such as Lusteron, Cronak, Iridite and Anozinc. *Hanson-VanWinkle-Munning Co.*

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METAL PROGRESS, 7301 Euclid Avenue, Cleveland 3, Ohio

December, 1951

758	788	818	848	878	908	938
759	789	819	849	879	909	939
760	790	820	850	880	910	940
761	791	821	851	881	911	941
762	792	822	852	882	912	942
763	793	823	853	883	913	943
764	794	824	854	884	914	944
765	795	825	855	885	915	945
766	796	826	856	886	916	946
767	797	827	857	887	917	947
768	798	828	858	888	918	948
769	799	829	859	889	919	949
770	800	830	860	890	920	950
771	801	831	861	891	921	951
772	802	832	862	892	922	952
773	803	833	863	893	923	953
774	804	834	864	894	924	954
775	805	835	865	895	925	955
776	806	836	866	896	926	956
777	807	837	867	897	927	957
778	808	838	868	898	928	958
779	809	839	869	899	929	
780	810	840	870	900	930	
781	811	841	871	901	931	
782	812	842	872	902	932	
783	813	843	873	903	933	
784	814	844	874	904	934	
785	815	845	875	905	935	
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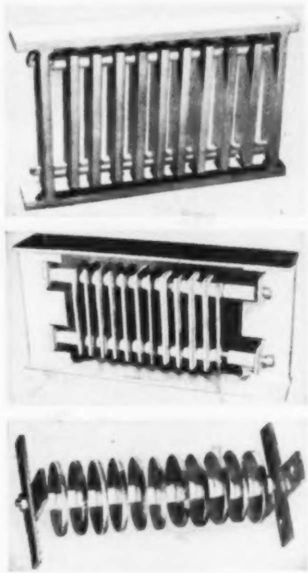

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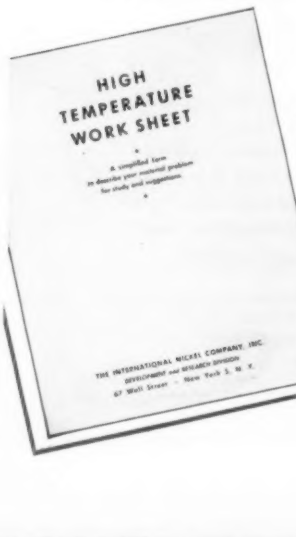

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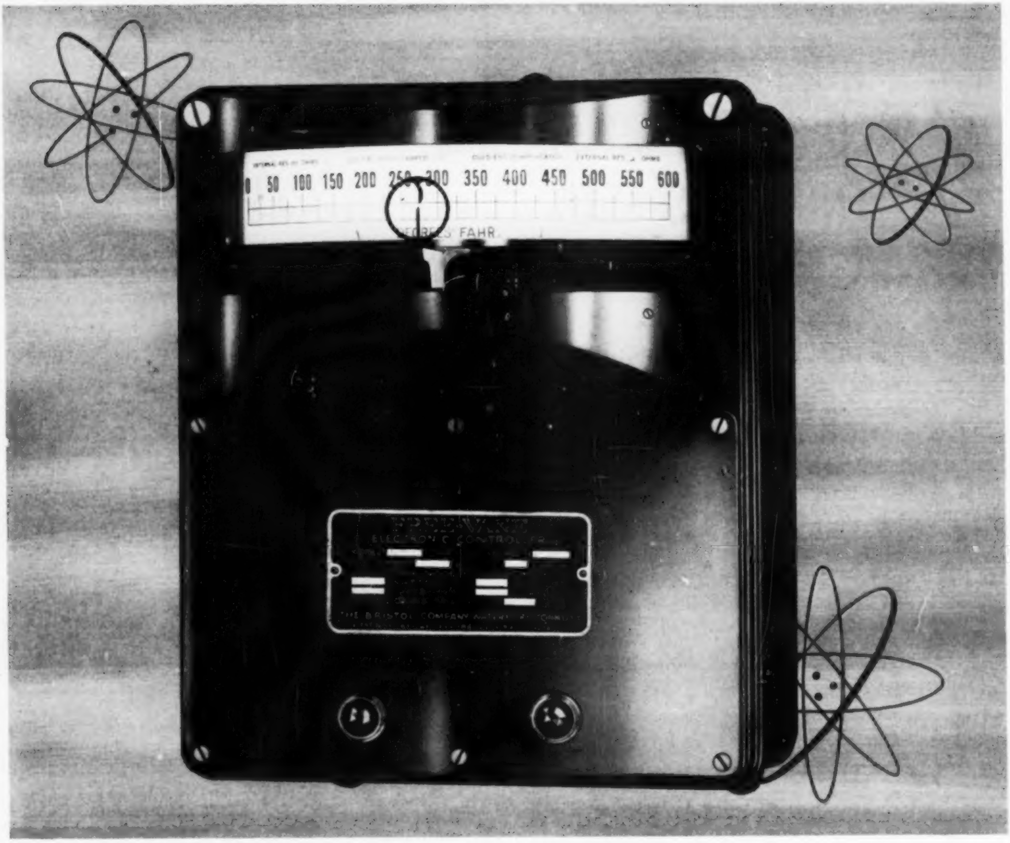

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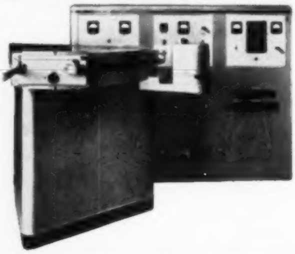

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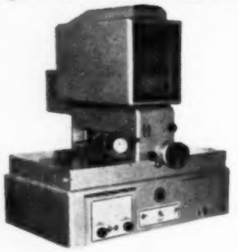

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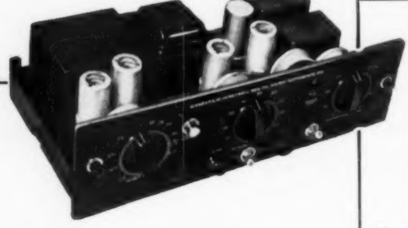

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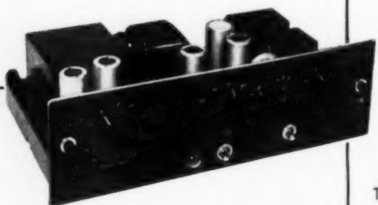
Electric Proportional Control Relay
With Automatic Reset

*Position-Proportioning control with automatic reset... **Electr-O-Line**.*

*The **Electr-O-Line** delivers a continuous heat input which is modulated according to exact process requirements. Individual control adjustments are included for proportional band, reset rate, approach rate and sensitivity. For complete information, write for Specification Number 194.*



Electr-O-Pulse

Electric Proportional Control Relay
With Automatic Reset

*Time-Proportioning control with automatic reset . . . **Electr-O-Pulse**.*

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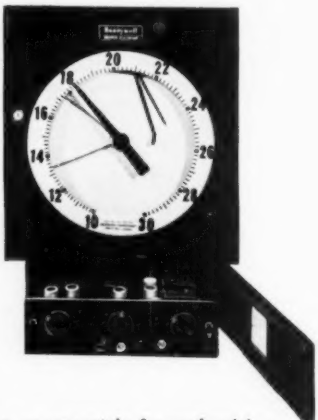

Electr-O-Line and *Electr-O-Pulse* proportional control relays provide the sensitivity, accuracy and speed required for the most critical control problems. They feature a plug-in cable connection to the controller, permitting unmatched mounting compactness and, therefore, a conservation of panel space.

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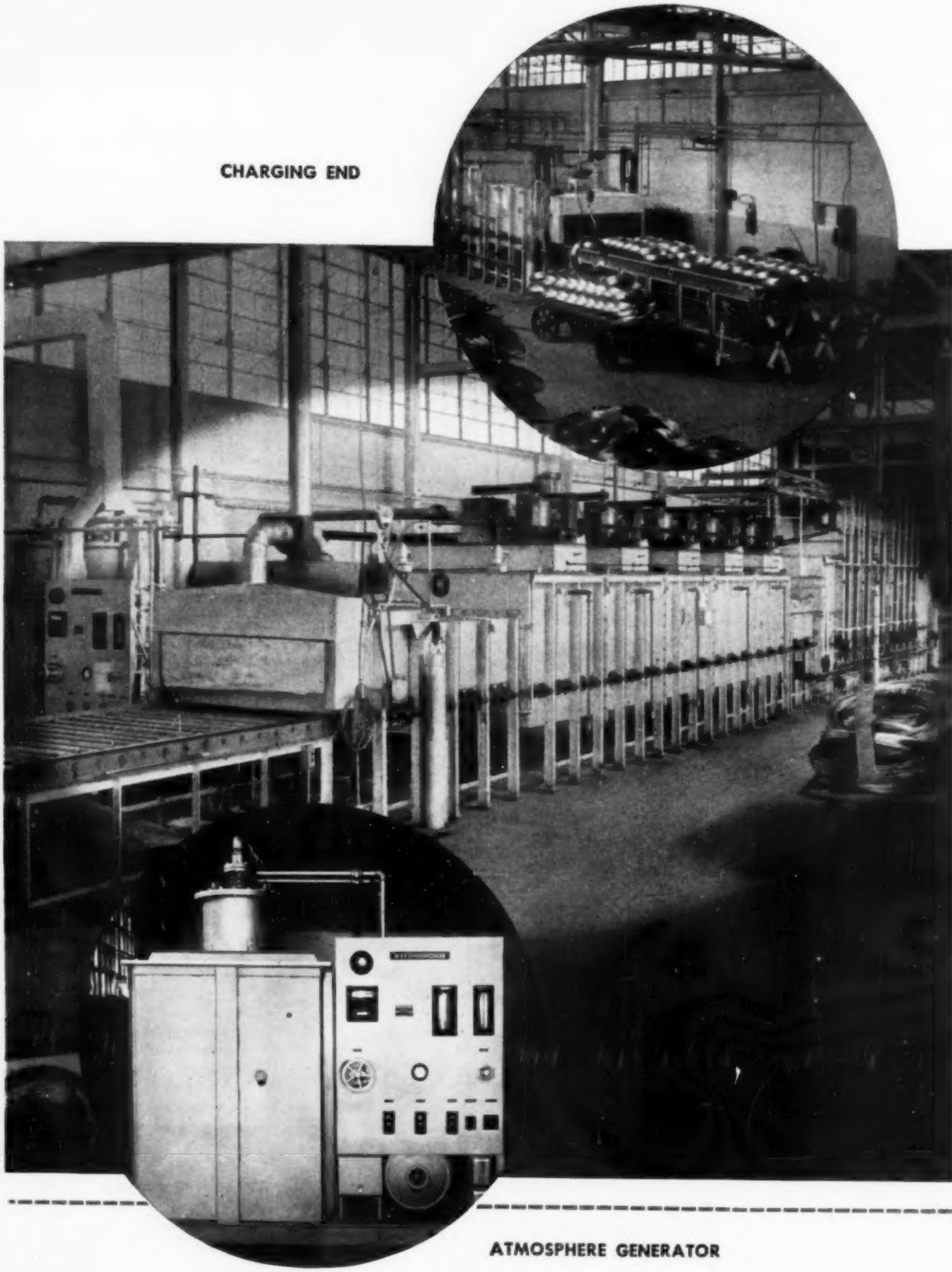

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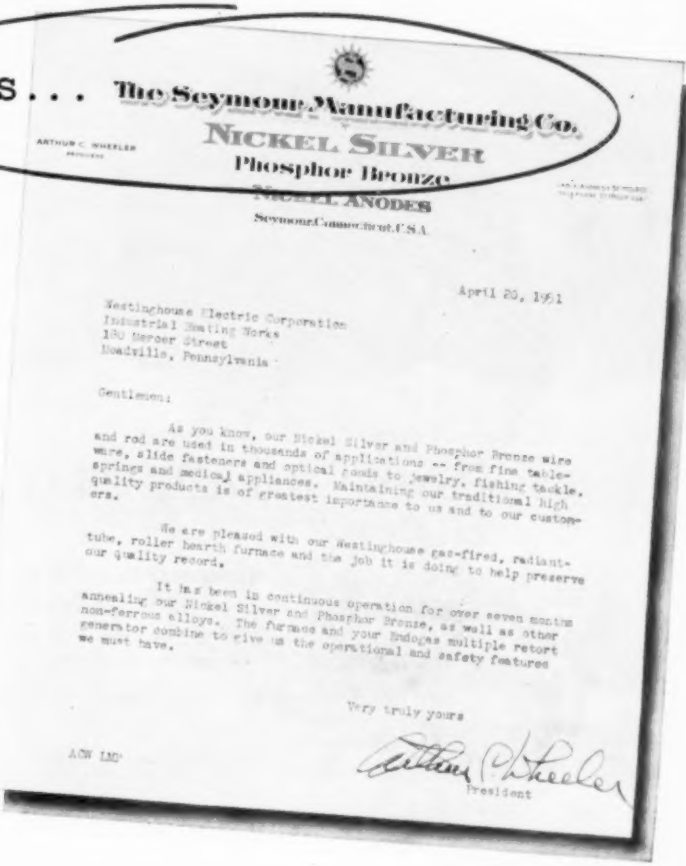
says . . .



The Seymour Manufacturing Co.

ARTHUR C. WHEELER

NICKEL SILVER

Phosphor Bronze

NICKEL ANODES

Seymour, Connecticut, U.S.A.

April 20, 1951

Westinghouse Electric Corporation
Industrial Heating Works
180 Mercer Street
Meadville, Pennsylvania

Gentlemen:

As you know, our Nickel Silver and Phosphor Bronze wire and rod are used in thousands of applications -- from fine tableware, slide fasteners and optical goods to jewelry, fishing tackle, springs and medical appliances. Maintaining our traditional high quality products is of greatest importance to us and to our customers.

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It has been in continuous operation for over seven months annealing our Nickel Silver and Phosphor Bronze, as well as other non-ferrous alloys. The furnace and your Endogas multiple retort generator combine to give us the operational and safety features we must have.

Very truly yours

Arthur C. Wheeler
President

ACW LMD

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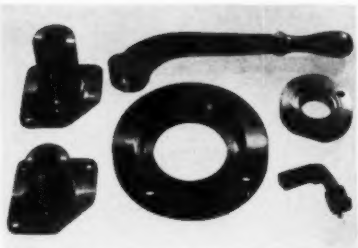

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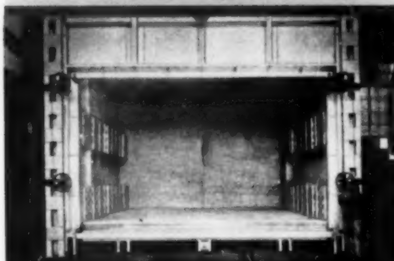
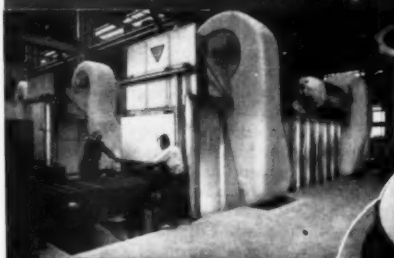


Despatch Stress Relief Furnace, gas fired car bottom type. Has automatic pre-heating, soaking and cooling control.



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MAGNESIUM

and the problem of

WEIGHT

in your product

From designer's board to customer's hands, weight in your product may be expensive. Weight enters into the cost of the raw material. Weight determines production methods and machinery requirements. It enters into the cost of labor and the cost of transportation. And in many products, extra weight is a costly penalty in sales results. Weight, wherever it is found, costs money.

Now, consider magnesium. Here is the world's lightest structural metal. Its weight is nearly 75% less than that of steel . . . 33% less than aluminum. Wherever design is based on weight limitations, this lightness permits the use of thicker, more rigid sections without a weight penalty. In thousands of applications, magnesium has permitted better design, better performance, more payload, and at the same time decreased costly weight.

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This Little "Pig" Was Drafted...

Today, magnesium like many other metals, is a tremendously important part of our defense effort, particularly where light weight is a specification in design. For instance, a B-36 bomber uses nearly 30,000 pounds of magnesium. But tomorrow, magnesium promises new horizons in the field of metal supply. *The seas, at our own shores, can provide 100,000,000 tons of magnesium per year for a million years without significantly reducing the supply!*

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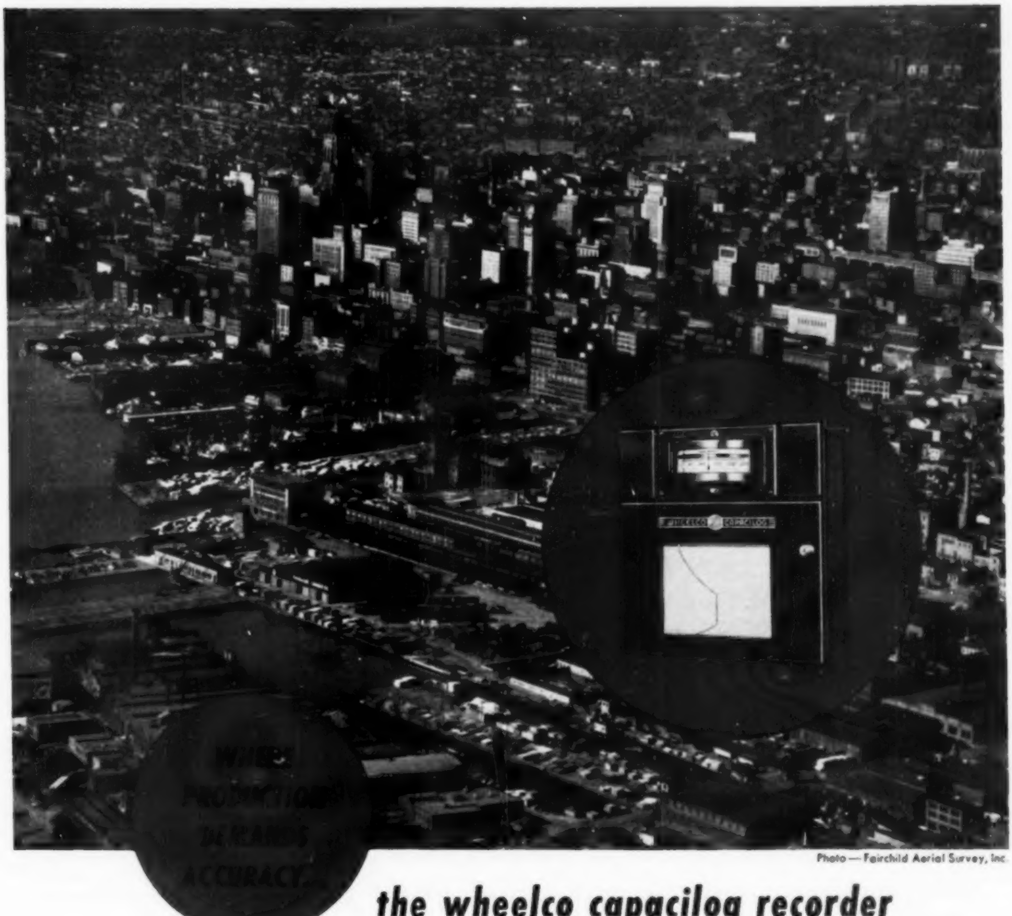

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the wheelco capacilog recorder

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Yes, for accuracy to ¼ of 1% of total scale, they specify the Wheelco Capacilog. Capacilogs are built for use with thermocouples and resistance thermometer measuring elements; as single or multipoint recorders; and with six different control combinations including pneumatic and proportioning types. Remember, in Baltimore and throughout the nation, wherever production demands accuracy, Wheelco Capacilog Recorders are specified.

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Wheelco Instruments Company, 835 W. Harrison Street, Chicago 7, Illinois

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Metal Progress

Vol. 60, No. 6 · December 1951

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Here's How to Remove

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Don't take today's alloys for granted. Order by hardenability from Ryerson and be doubly sure. Some shortages are inevitable, but, as always, we'll do everything possible to meet your requirements. So, for any steel need, phone the Ryerson plant nearest you.

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Metallurgy at the Bureau of Standards in the Past 50 Years

By John G. Thompson
Chief
Metallurgy Division
National Bureau of Standards
Washington, D. C.

THE NATIONAL BUREAU OF STANDARDS this year observes the semicentennial of its establishment in 1901. The original organization consisted of six divisions, concerned with the establishment and maintenance of standards in the fields of electricity, weights and measures, heat and power, optics, chemistry, and mechanics.

Determinations of the properties and behavior of metals were carried on in connection with this establishment and maintenance of standards also. In July 1913, the Metallurgy Division was organized with the late George K. Burgess as its first chief, and a staff consisting of John J. Crowe, Henry S. Rawdon, Howard Scott, and R. G. Waltenberg.* The justification for establishing a new division for concentrated work in metallurgy was presented by Dr. Burgess in 1916, as follows:

"The available knowledge concerning properties of metals and alloys and the dependence of these properties upon what we may call the life history of these metals, including their pedigree, or preparation and composition, and conditions of birth, or their manufacture, is all too meager, both in quantity and quality."

Enlarging upon this theme he quoted Prof. Henry LeChatelier as follows:

"Concerning the physical properties of alloys, it is impossible to find numerical data worthy of any confidence. This comes from the fact that, on the one hand, experiments have been made by physicists too disdainful of chemical analysis, and on the other hand by chemists unfamiliar with physical measurements. It would be impossible in some cases to repeat to within 50% results which were nevertheless measured with a precision of one in a thousand, on account of lack of sufficient indications as to the composition of the alloy studied; again, several measurements made on alloys of exactly determined composition do not agree among themselves to 10%. Practically, it is only for the melting points of alloys that we possess somewhat accurate information."

The quotation from Professor LeChatelier was extended by Dr. Burgess' own comments, "This statement by Professor LeChatelier is by no means an exaggeration, and that such conditions as he describes with respect to the metallic alloys may exist appears to be due, in part at least, to a lack of appreciation of the importance of the history of the materials which are being studied. How many precise measurements, for example, have been made on material described merely as 'iron', the results of which are oftentimes meaningless because of lack of a sufficient and necessary knowledge of chemical composition, mechanical heat treatment, and thermal history?"

The scope of the new division included the production of ferrous and nonferrous metals and alloys, including "pure" metals, and the determination of their constitution, composition, properties, fabrication, heat treatment, and utilization. This broad coverage of the field of physical metallurgy represented quite an undertaking for a staff of five, including the division chief, and a program of expansion was undertaken. Among the first additions to the staff, in 1914, were Paul D. Merica and Raymond W. Woodward.* In 1916 J. R. Cain and his co-workers were transferred from the Chemistry Division to constitute a section of Chemical Metallurgy in the new division. Completion of a new building in 1918 provided improved facilities for the growing division and by 1920 the names of Samuel Epstein, John R. Freeman, Jr., Herbert J. French, Marcus A. Grossmann, Louis Jordan, and James S. Vanick* had been added to the roster; A. L. Boegehold had served at the Bureau on detail from the Army's Ordnance Department. When Dr. Burgess became Director of the Bureau in 1923, personnel of the Metallurgy Division totaled about 45.

Interests of the Metallurgy Division during its first ten years were numerous and varied in character. In this review it is possible to cite only a few subjects of outstanding and per-

*Present locations of these early staff members are given in the footnote on p. 52.

manent interest and to confine personal mention to the guiding spirits, regardless of the merits of the contributions of the co-workers.

The work of Burgess and his co-workers on pyrometry and melting point determinations, critical points in iron and other metals, fusible tin boiler plugs, production of high-purity platinum, and production of sound ingots and steel rails deserves special mention. Burgess was the leader in the important investigation of the effect of sulphur and phosphorus in steel which continued for a number of years under the cooperative sponsorship of the National Bureau of Standards, American Society for Testing Materials, and the U. S. Railroad Administration.

Probably the outstanding item of these early days was the work of Paul D. Merica and associates on the constitution of aluminum alloys. It culminated in 1919 in the publication by Merica, Waltenberg, and Scott, of the first adequate explanation of the mechanism of the age hardening of duralumin. It was shown that the compound $CuAl_2$ was retained in supersaturated solid solution during quenching, and was subsequently precipitated (with consequent strengthening and hardening of the alloy) as a result of aging at low temperatures. These observations led to the recognition and understanding of many other examples of "precipitation hardening", or "aging", in both laboratory and commercial metals and alloys.

Henry S. Rawdon made valuable contributions in the fields of metallography, microstructure, stress-corrosion, corrosion, and protective metallic coatings. Production of high-purity iron and studies of gases in metals were started by J. R. Cain and continued by his successor, Louis Jordan. The problem of the malleability of nickel was solved by Merica and Waltenberg. The work of Howard Scott on dimensional changes of steel during hardening, and Rawdon's results on the hardening of spark-fused high-purity iron, were useful in the subsequent development of the theory of the hardening of steel. Herbert J. French began his pioneer work on high-temperature properties of metals and methods of testing. John R. Freeman, Jr., determined the constitution of alloys of iron and nickel. Samuel Epstein investigated the microstructure of "dirty" steels.

The preparation of circulars, each comprising an assembly and critical review of available information on a particular metal, or subject, was an important activity in the early days of the Division, when metallurgical information was fragmentary, widely scattered, and not always completely reliable. Prior to 1923 the Division produced circulars on Aluminum and Its Light Alloys; Protective Metal Coatings for Rust-Proofing Iron and Steel; Melting Points of Chemical Elements and Other Standard Temperatures; Nickel; Analysis of Iron and Manganese Ores; Strengths and Related Properties of Metals and Certain Other Engineering Materials; Metallographic Testing; Structure and Related Properties of Metals; Copper; Invar and Related Nickel Steels. The demand for these circulars, plus the rapid advances in metallurgical knowledge in those days, made their maintenance and revision a major undertaking.

EARLY WORK ON UNUSUAL ALLOYS

The early records of the Division remind us that interest in such alloying elements as boron, cerium, titanium, uranium, and zirconium is not new. During World War I, the War Department and the Navy sponsored investigations of

Early N.B.S. Staff Members

John J. Crowe is now assistant vice-president of Air Reduction Co., Inc., Murray Hill, N. J.

Henry S. Rawdon is now retired from National Bureau of Standards and lives in Bethesda, Md.

Howard Scott is manager of Metallurgical and Ceramic Department of the Research Laboratories of Westinghouse Electric Corp. at East Pittsburgh, Pa.

R. G. Waltenberg has retired from H. A. Wilson Co., Newark, N. J., and lives in Onancock, Va.

Paul D. Merica is now executive vice-president of International Nickel Co. of Canada, Ltd., New York City.

Raymond W. Woodward is director, Electronics Division, General Research Laboratory, Underwood Corp., Hartford, Conn.

J. R. Cain, consultant in chemical and metallurgical engineering, died in 1948.

Samuel Epstein is now research engineer for Bethlehem Steel Co. in Bethlehem, Pa.

John R. Freeman, Jr., is technical manager for American Brass Co., Waterbury, Conn.

Herbert J. French (past-president ⊕) is vice-president of International Nickel Co., Inc., New York City; assistant vice-president, International Nickel Co. of Canada, Ltd., New York City.

Marcus A. Grossmann (past-president ⊕) is advisor, Research Planning, U. S. Steel Co., Pittsburgh, Pa.

Louis Jordan is executive secretary of the Division of Engineering and Industrial Research, National Research Council, Washington, D. C.

James S. Vanick is metallurgical engineer for International Nickel Co., New York City.

A. L. Boegehold (past-president ⊕) is head of the metallurgical department, Research Laboratories Division, General Motors Corp., Detroit.

American Society for Metals

to

National Bureau of Standards

On the occasion of the 50th Anniversary of the National Bureau of Standards, the American Society for Metals presents its congratulations. Fortunate it was that when the metallurgical division was established 38 years ago, the late, great George Kimball Burgess (fourth President of our own Society) was made its chief. The high goals he set for the original group of five men have guided their successors until today, and are an earnest of the fruitful years ahead. The early studies and discoveries in the art of high-temperature measurement, the quench hardening of steel, the age hardening of aluminum, and the measurement of gas in metals have had the widest application in the metallurgical industry everywhere. More recent notable achievements in the study of high-purity iron, wire for suspension bridges, and plating for welded ships will match the earlier work in importance.

Again, 20,000 metallurgists comprising the American Society for Metals hail the National Bureau of Standards and bid it God speed!

W. H. Eisenman
Secretary

Walter Jominy
President

these and other alloying elements for ordnance uses. Many of the ingots were prepared by the Bureau of Mines and other agencies, but were hot rolled to plate by Raymond Woodward and physical properties of the plates were determined by others in the National Bureau of Standards.

The late Horace W. Gillett was the second chief of the Division, transferring from the Bureau of Mines in March 1924 and departing in June 1929 to become the first director of Battelle Memorial Institute. During his regime the Division continued to expand as a result of his broad interests and versatility. Cooperation with technical societies and the study, under the Research Associate plan, of problems of particular interest to industrial groups, were prevalent in the boom times preceding 1929.

During this period Rawdon made numerous contributions in the fields of corrosion, corrosion testing and (with the late E. C. Groesbeck) in metallography. His "Protective Metallic Coatings", Monograph No. 40 in the American Chemical Society's series, is authoritative. Corrosion embrittlement of duralumin and its mitigation by proper heat treatment and protective coatings were the subject of several investigations. Demonstration of the value of a protective coating of pure aluminum sprayed on duralumin was an achievement of the Division which antedated the commercial production of Alclad material.

French continued his pioneer work on high-temperature properties of metals and methods of testing and was awarded the Henry Marion Howe medal for the best paper in *Transactions* of the American Society for Steel Treating (now the American Society for Metals) in 1930. His work (with O. Z. Klopsch) on the mechanism of the quenching of steel had important commercial consequences. An extended investigation of machinability was started. Freeman showed that the alleged allotropy of zinc did not exist, and contributed to our knowledge of the properties of babbitt, of the endurance properties of rail steel, and of the tensile properties of soldered joints under prolonged stress.

Jordan did pioneer work on gases in metals and developed vacuum fusion into a practical and useful tool for the determination of oxygen, nitrogen, and hydrogen in steel. To provide special crucibles for laboratory melting of unusual metals such as spectroscopically pure platinum, Jordan developed procedures for purifying magnesia, zirconia, beryllia and thoria and for fabricating these products into useful shape. Another of his achievements was a report on tarnish-resisting silver alloys of sterling grade.

Scott continued his valuable contributions on dimensional changes of steel during tempering and aging, and on the origin of quenching cracks. Epstein's work on normal and abnormal steels was meritorious and his construction of an automatic metallographic polishing machine was a pioneer effort in that field. William H. Swanger developed procedures for mechanically working rhodium, a metal previously considered unworkable. Harry K. Herschman showed that air hardening steels supplied greatly improved performance as rivets in military tanks. In the experimental foundry, C. M. Saeger, Jr., started the Bureau's cooperative work with American Foundrymen's Society on the testing and specification of molding sands.

Various members of the staff collaborated in preparing "Principles of the Heat Treatment of Steel", which was published by the American Society for Steel Treating in 1928, and was used as a school and university textbook. The circular "Light Metals and Alloys", published in 1918, was revised and reissued in 1927. Dr. Gillett was one of the founders, in 1927, of Alloys of Iron Research under the sponsorship of Engineering Foundation.

In 1929, H. S. Rawdon became the third chief of the Metallurgy Division, and served until he retired in 1945. Important contributions to the science and practice of metallurgy were made during the 1930's, in spite of the effects of the depression on budget and personnel, particularly with respect to Research Associate activities.

THE DEPRESSION AND THE WAR

In the field of the preparation and determination of the properties of pure metals, reports were made on nickel, bismuth, thorium, and the Bureau's own pure iron project. Nickel of 99.94% purity, the highest purity available up to that time, was supplied by the International Nickel Co., Inc.; Jordan and Swanger developed techniques for melting and working this high-purity metal and assembled its properties as determined in various laboratories throughout the Bureau. Many of these determinations are still recorded as the properties of pure nickel. Bismuth was studied by John G. Thompson, Research Associate for Cerro de Pasco Copper Corp., in an attempt to expand the uses of this metal. The available information was compiled in Circular 382, and the study of various alloys of bismuth paved the way for subsequent industrial uses for fusible alloys containing bismuth. Thorium was a new metal in 1930 and the various laboratories of the Bureau cooperated in the study of a limited amount of commercially

produced metal, reportedly of 99.7 or 99.8% purity, prepared by calcium reduction and by electrolytic methods.

Preparation of iron of the highest possible purity and its alloys had been of interest to the Metallurgy Division throughout its history. Electrolytic iron was carefully prepared by Cain and his co-workers before 1920, and its alloys with carbon, silicon, sulphur, and manganese were studied. In the early 1930's, when the history of pure iron was reviewed in preparing "The Metal — Iron" for the Alloys of Iron Monograph Series, it was evident that none of the earlier irons could be considered as "pure" in view of the limitations in scope and reliability of the reported analyses and of the important effect of very minute amounts of certain impurities. In attempts to improve upon the purity of electrolytic iron, a process was developed which involved chemical purification of an iron salt and conversion of the purified product, in successive steps, to iron oxide, sponge iron, and small melted ingots. Thompson and Cleaves reported that iron, 99.99% pure according to exhaustive analyses by chemical and spectrochemical methods, was obtained, having the highest established purity to that time in this country or abroad. Work along similar lines was revived after World War II.

During Rawdon's term as chief of the Division the extended cooperative investigations of rail steel and of the effect of phosphorus and sulphur in steel were concluded. The final report on sulphur in steel was published for the Joint Committee by the American Society for Testing Materials in 1936.

Identification of a secondary brittle range in steel at about 550° C. (1025° F.) by John R. Freeman, Jr., and G. W. Quick was a factor in the development of controlled cooling rates in rolling mill practice, which supplied a practical solution to the problem of shatter cracks in railroad rails before hydrogen was identified as an important factor.

Thomas G. Digges' contributions in the field of machinability of steel and machinability test methods were meritorious, and were followed by useful contributions on the factors affecting austenitic grain size and on critical cooling rates. The late W. H. Mutchler's study of corrosion by marine exposure of light sheet metals for aircraft use produced results of great value to the Government and to the aircraft industry. R. W. Buzzard's work on anodizing aluminum and magnesium alloys in chromic acid baths, sponsored by the Bureau of Aeronautics, resulted in numerous patents and furnished the basis for Navy specifications that are still in use. A report by H. H. Walkup and E. C. Groesbeck on factors affecting the Preece test for zinc coatings accelerated the controversy that is still in existence.

D. J. McAdam, Jr., completed his work on stress-corrosion and corrosion-fatigue of metals in various media and began a ten-year program of notable achievements, with R. W. Mebs, G. W. Geil, and J. A. Bennett, on the flow, fracture, and ductility of metals. S. J. Rosenberg and Louis Jordan made the first study reported in this country of the effect of different atmospheres on the wear of steel and showed that adherent films of oxide serve to prevent wear.

FAULTY BRIDGE WIRE

The study by the late Wm. H. Swanger and G. F. Wohlgemuth of the failure of wire cables of the Mt. Hope, Rhode Island, bridge was awarded the Charles B. Dudley medal for 1936 by the American Society for Testing Materials. Swanger also made valuable studies of special refractories for high temperatures, and of the cold treating of metals to produce shrink fits. His work, with A. R. Maupin, on the strength and creep of soldered joints in copper pipe lines was of value to the building trade. S. M. Shelton's determinations of thermal conductivities of ferrous materials over the range from 100 to 500° C. continue to be quoted frequently.

Herbert C. Vacher's work on carbon-oxygen equilibria in liquid iron maintained the high standards of the Bureau's work in the field of gases in metals, and an international cooperative study of methods for the determination of oxygen in steel (reported by Thompson, Vacher, and Bright in 1937) established the merits and reliability of the vacuum fusion method.

The late A. J. Dornblatt, research associate for the American Silver Producers Assoc., directed metallurgical work on silver and its alloys at the Bureau and served as principal liaison officer with other laboratories that cooperated in a three-year study of industrial uses for silver. Results obtained in the silver project were compiled in the 1940 book "Silver in Industry", edited by Lawrence Addicks.

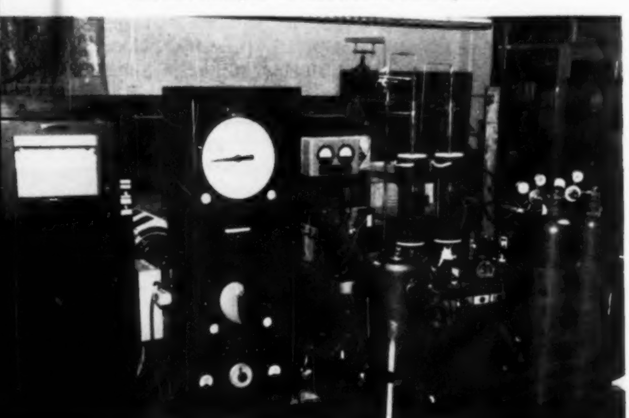
In the field of foundry metallurgy, C. M. Saeger and A. I. Krynitsky developed a fluidity spiral to measure the running quality of metal, improved the methods for preparing cast iron test bars, and perfected a procedure for measuring deflection in transverse test bars all the way to fracture of the specimen. Saeger's development of rubber binders and coatings for cores

and molds resulted in several patents and has had numerous industrial applications. Krynitsky studied the elastic properties of cast irons and, in 1941, recorded the presence of nodular graphite in some as-cast, low-alloy iron.

Useful information on bearing bronzes and white metal bearing alloys was developed by Harry K. Herschman. The use of oxalic acid as an electrolytic etchant for welded stainless steel, reported by G. A. Ellinger, has since found numerous applications for other metals. H. L. Logan showed that electrode potential was related to the susceptibility of duralumin to intercrystalline corrosion and determined the cooling rates necessary to control this susceptibility.

The Navy Department requested cooperation in the Bureau of Ships' program to develop procedures for welding ship plate and structural steel of greater thickness than had previously been considered weldable. The Bureau's contribution was the development of metallographic and metallurgical evaluation of experimental welds; as a byproduct G. A. Ellinger and M. L. Williams (with A. G. Bissell of the Bureau of Ships) were awarded the American Welding Society's Lincoln medal in 1942 for their development of the Tee-bend test. In subsequent examination of fractured plates from welded ships, Ellinger and Williams showed that all the tested plates met specification requirements; fractures always started at a notch, either structural, mechanical, or metallurgical; and that plates in which fractures originated or which were traversed by fractures, had relatively low Charpy impact values and high transition temperatures — that is, temperatures where ductile fracture changes to brittle fracture. Susceptibility of ship plate to fracture evidently can be predicted by means of impact and transition temperature tests, but it is not yet clear why certain plates are notch sensitive and susceptible to the propagation of fractures.

Thermal Analysis in Controlled Atmosphere



During World War II much of the work of the Division was of a confidential nature and the results (if published at all) did not appear until after H. S. Rawdon had retired as division chief in 1945, and had been succeeded by the present author. The latter had had the unusual experience of participating in metallurgical work with uranium in both World Wars I and II.

ACCOMPLISHMENTS SINCE 1945

Work on the effect of temperature, stress system, strain rate, and prior history on the flow, fracture, and ductility of metals was conducted under the supervision of D. J. McAdam until his retirement in 1947 when T. G. Digges took over. McAdam's work did much to clarify the mechanism of the fracture of metals. G. W. Geil made a mechanical gage for measuring reduction of area to ±0.0001 in. for tension tests in the range from +100 to −196° C., where true fracture stress and the strain at fracture cannot be determined accurately from diameter measurements made after fracture of a ductile metal. Current projects include studies of the mechanism of plastic deformation in each of the three stages of creep, and of the mechanism of deformation and fracture at temperatures down to the boiling point of liquid nitrogen. A new project in this section is a study, in cooperation with the Electronics Division, of solid metals for use in ultrasonic delay lines, a "memory system" for storing received signals without appreciable attenuation or distortion.

Thomas G. Digges' wartime work on the effect of boron on various properties of commercial and laboratory steels showed that boron enhances hardenability and decreases the rate of nucleation of ferrite and carbide, because of its effects on the solid solution at heat treatment temperatures. S. J. Rosenberg's study, supported by the U. S. Navy's Bureau of Aeronautics, of the stabilization of carbides in 18-8 stainless steel by titanium and columbium, to avoid intergranular corrosion during service at high temperatures, resulted in changes in Navy specifications and in production practice. His recent work has shown that solubility of carbon in 18-10 austenite is less than had been believed, and has established the solubility limits between 800 and 1975° F.

H. E. Cleaves and his co-workers have revived the "pure iron projects" and are attempting larger scale production of iron of at least 99.99% purity.

R. A. Lindberg developed improved techniques for slip-casting beryllia and other special refractories for melting highly purified metals. V. C. F. Holm's paper on the usefulness of several resinous sealants to correct porosity in metal castings has been in considerable demand, while the contributions of Krynitsky and co-workers to the testing and specification of foundry sands have been particularly useful to members of the American Foundrymen's Society. Harry Stern's work on the mechanism of the formation of nodular graphite in cast iron is producing interesting results in the malleable iron industry.

Fatigue of metals has been investigated in several projects in recent years. J. A. Bennett has done excellent work on the nature of fatigue damage, its early detection, and its possible cure or amelioration. The paper by H. L. Logan on his wartime work (sponsored by the Bureau of Aeronautics) on the effect of chromium plating on fatigue of aircraft metals was an important contribution.

In this same field Harry K. Herschman showed that composite electroformed printing plates, used by the Bureau of Engraving and Printing, had better resistance to fatigue in printing operations if they were joined to their blocks by plastic adhesions instead of solder.

Underground Corrosion — In postwar reorganizations, the Bureau's work in this field was transferred to the jurisdiction of the Metallurgy Division. The program of exposure tests, conducted during the past 30 years by K. H. Logan and others with cooperation of pipe line, public utility and manufacturing organizations, is being completed by I. A. Denison. Corrosion data have been obtained from approximately 35,000 specimens, representing more than 300 varieties of metals and protective coatings, distributed in more than 100 test sites throughout the United States. The Bureau has established the test procedure for underground corrosion and has accumulated a vast amount of data which has been made available to the public, but the program of exposure tests is apparently reaching the point of diminishing returns. After completion of the current program, in 1952, when the last of the previously buried specimens will be disinterred, any further tests of new materials or in new exposure sites necessarily must be sponsored activities conducted under the Research Associate plan. The exposure program has been supplemented by laboratory work which at present is particularly concerned with theoretical and practical aspects of cathodic protection; for example, H. D. Holler's important contributions to the controversial question of the measurement of corrosion while it is occurring underground. In studies of the corrosion of metals in other environments, H. L. Logan is making good progress in his work on the mechanism of stress-corrosion, and F. M. Reinhart is continuing the long-standing study of the corrosion of light metals for aircraft use, under the joint sponsorship of the Bureau of Aeronautics, National Advisory Committee for Aeronautics, and Wright Air Development Center.

Investigation, for other Government agencies, of failures of metals in service in transportation equipment on land and sea and in the air has receded somewhat from its wartime peak but is still active.

PRESENT ORGANIZATION

The Metallurgy Division, and the entire National Bureau of Standards, has benefited from a postwar program of reorganization and modernization. Renovation and redecoration of the building in which the Division is housed have improved working conditions. Replacement of obsolete equipment and installation of new has appreciably improved facilities; further improvement in facilities and quarters is contemplated.

The work of the Division is now conducted in four sections of approximately equal size:

T. G. Digges is in charge of Section 1, Thermal Metallurgy.

H. E. Cleaves is in charge of Section 2, Chemical Metallurgy.

J. A. Bennett is in charge of Section 3, Mechanical Metallurgy.

G. A. Ellinger is in charge of Section 4, Corrosion Metallurgy.

Activities in the four sections have been sketchily indicated; work for other Government agencies — particularly in connection with the defense effort — is expanding as fast as limitations of space and personnel will permit. The staff at present comprises approximately 70, with service records ranging up to 31 years, and with an average of 9.6 years length for employees of professional status.

The Metallurgy Division offers opportunities for qualified metallurgists, of any grade recognized by the Civil Service Commission, to conduct or assist in metallurgical research in the field of physical metallurgy, under conditions which approximate the freedom of university life. Members of the staff are encouraged to participate in extracurricular activities and particularly in the world of technical and scientific societies.

John Chipman

President
American Society for Metals

Chairmen of ASM Chapters, when they introduce President John Chipman, need not fear boring him by telling about our "second oldest profession", or using metallurgical double-talk about the platinum blonde with the bivalent gleam in her steel blue eyes. Those allusions are as palatable to him as the shrimps on which he was reared along the Mississippi Gulf Coast, or the lobsters which he now can easily get in Cambridge, where he heads Massachusetts Institute of Technology's department of metallurgy. Besides, Professor Chipman, who naturally looks like a Cape Cod vestryman, can slyly slip a metallurgical naughtiness of his own into his talk, when he is obliged to rouse an audience of work-a-day metallurgists.

Unpleasantly, and unfortunately, rouse them is just what he has to do altogether too often. Metallurgists control the very core of our 20th century civilization and are fixing our future. They are leading us away from total dependence on the eight or ten metals known since the beginning of history and introducing us to the possibilities — as yet but dimly known, but certainly enormous — of the 60 or more other metals in the periodic sequence.

Unfortunately, the average citizen doesn't know anything about metallurgy and the metallurgist. In fact, when the scientists in charge of the early study of the atomic bomb wanted to camouflage a diversity of fundamental work on the chain reaction it was "cryptically named 'Metallurgical Laboratory' of the University of Chicago", in the words of the Smyth Report. (We can pause here long enough to note that Chipman supervised the truly metallurgical investigations on uranium metal and materials of pile construction of the "Metallurgical Laboratory" as well as associated problems at home base in Cambridge.)

An announced objective of the new President of the American Society for Metals is to improve the education of Americans generally as to what metallurgy is and why, to preach the gospel that young men will do well to educate themselves as metallurgists, and finally to wake up the present metallurgists to their importance in the scheme of things.

President Chipman has had some good grounding in fervid preaching. His father (John Chipman, too, a New York civil and mining engineer who went to Florida in 1877) was ordained in the Episcopal ministry, and long held the pastorate of St. John's Church in Pascagoula, Miss., on the Gulf Coast. Two and a half centuries earlier, the first American Chipman, also a John, became an elder in the church at Barnstable on Cape Cod.

President Chipman, however, is basically a learned educator of metallurgists. He reached that goal by a peripatetic education of his own, starting with chemistry. He attended the University of the South, because it was a good chemistry and liberal arts school and took him back after a hitch in the World War I field artillery (buck private to 2nd lieutenant). Next came the University of Iowa, because he could get a job as teaching assistant while working for his M.S. degree; then Illinois Wesleyan, where he taught chemistry and there he met, wooed and married Ruth Hayes, a Peoria, Ill., girl who had done postgraduate work in botany; University of California, where both could earn their doctorates and, in particular, benefit from the mentorship of the late Gilbert N. Lewis; Georgia Tech, to have a job and contribute something to his native South as a teacher; University of Michigan, as a research engineer; American Rolling Mills at Middletown, Ohio, as associate director of research laboratories; and finally Massachusetts Institute of Technology as professor of metallurgy (since 1937) and head of the department of metallurgy (since 1946).

All along he had been publishing papers in scientific and technical journals, some 60 of them, which demonstrated his authority on reactions in liquid metals, vapor pressure, chemical equilibrium at high temperatures, and steelmaking. This has naturally acquired him professional honors: ASM's Henry Marion Howe Medal in 1934 for his paper in *Transactions* which has become a classic ("Applications of Thermodynamics to the Deoxidation of Liquid Steel"); the Hunt Award of American Institute of Mining and Metallurgical Engineers in 1939; University of the South's honorary Sc.D. in 1940; ASM's Campbell Memorial Lectureship in 1942 ("Chemistry at 1600"); A.I.M.E.'s Howe Lectureship in 1949 ("What Is Metallurgy?"); and last October, the Franklin Institute's silver Francis J. Clamer Medal "for meritorious

achievement in the field of metallurgy". The Royal Academy of Sciences of Sweden has also honored him by electing him a foreign member.

The Chipmans live in shady Winchester, Mass., just beyond Cambridge. Their elder child, David Randolph, is doing research in physics at M.I.T. Daughter Ruth Elizabeth is studying anthropology at Cornell. Father John diverts himself with photography, fishing and sailing. From his various travels he likes to bring home varieties of *Labiatae mentha* (mint to you), primarily for Mrs. Chipman's botanical garden, secondarily for a well-known drink popular in the South.

At Massachusetts Institute of Technology Professor Chipman has organized a metallurgical curriculum and built up unexampled laboratories which offer two options, one in metallurgy, the other in mineral engineering.

The metallurgy course provides a broad training in the science of metals and the engineering involved in their production and conversion to useful products.

Mineral engineering includes all phases of beneficiation, extraction and purification — physical and chemical — of valuable constituents from ores, solid fuels, ceramic raw materials and other mineral substances.

Graduate students at M.I.T. can enroll for degrees of Master of Science in Metallurgy, Master of Science in Ceramics, Metallurgical Engineer, Mineral Engineer, or Doctor of Science in Metallurgy, in Mineral Engineering or in Ceramics.

Aside from his executive duties and supervision of research and graduate work, Professor Chipman lectures to fourth-year students on metallurgical thermodynamics, and to graduate students on the principles of steelmaking.

To President Chipman as educator it does not matter much by what route a student eventually reaches metallurgy. Says he: "A student of metallurgy devotes only about one third of his effort during a four-year course to studies of metallurgy. Half of his time is spent on basic science and engineering, nearly 20% on the arts and humanities, and one third on his specialty. A large portion of the entire field of metallurgy must be omitted — and in fact should be. It is quite feasible, nonetheless, to teach the fundamentals of most of the pertinent subjects, provided the student is not overburdened with mere description or with a plethora of specific applications. It is far more important, for example, that he have a real grasp of physical chemistry than that he know the dimensions of the biggest blast furnace."

This catholic approach to the halls of metallurgy was foreshadowed by his own experience. Asked why he — a specialist in physical chemistry — should go to work on reactions in molten metallic systems, the reply was, "It looked like it was about time somebody did."

The number of juniors and seniors at M.I.T. (40 in each class) is a pedagogic miracle of evangelical Chipman persuasiveness. During the past five years there have been an average of only four freshman students intending at that early stage to become metallurgists, but Professor Chipman, his faculty and his upperclassmen convince the others that they should transfer.

In his department Chipman has 25 faculty, most of them ASMembers, including his executive officer, Prof. Carl F. Floe. He has 102 graduate students, 12 of them in ceramics.

Obviously the presence of such a large body of graduate students in metallurgy is related to the superlative equipment and instruction available in Cambridge. That being established, John Chipman's present ambition is to broaden the undergraduate base, to multiply the present meager enrollment in the metallurgical courses offered in so many colleges and universities on this continent. He believes that the American Society for Metals can be a powerful instrument in attaining this objective.

If the ⊕'s diverse activities in past years can be summarized in a few words, it might be said that they were primarily directed toward spreading new information among its members — metallurgists and metal engineers who need to keep abreast of developments in their field, and who for the most part were not educated primarily for metallurgy — rather as mechanical or chemical engineers. Chipman's ambition is to turn some of the strong resources of the Society toward the recruitment of young men by intensifying the present promotional work — "advertising" the metals engineer, if you will — so that parents will know something about metallurgy, by a more consistent educational campaign among science teachers and student advisers in high schools, by propaganda originating in each Chapter and in fact in each ASMember, by the establishment of teaching awards, and like activities.

This is truly an educational program. Very much of it John Chipman wants to put into effect, or at least get well started, during this brief year as president. He ought to be able to do so, for he is a superb scholar, educator and administrator.

MYRON WEISS

New Atomic Weapons*

TODAY the United States stands before the world with the lamp of liberty raised high in one hand and the atomic bomb in the other. To many people — both at home and abroad — this is a spectacle that is more fearsome than comforting. They have no difficulty in imagining the suffering and desolation among innocent civilians that would follow in the wake of an all-out, global atomic war. [Consequently] many sincere people have asked, "Is the United States really pursuing the right course?"

I believe that we are, insofar as moral considerations influence the actions we take. Up to the present, in our period of atomic world leadership, we have undoubtedly taken the moral factor into account. I think it will forever redound to our credit that during the postwar period when we had exclusive possession of the atomic bomb we never once resorted to its use to settle our international differences.

Unfortunately, I believe, the Communists have been aware of the important role played by the moral factor in our deliberations and they have counted on it and taken advantage of it. They have been left free to pursue an atomic program of their own which they may well hope may cancel out this weapon.

You may ask why I raise these questions today. I raise them because, through our atomic energy expansion program and recent technological developments in the atomic weapons field, we are entering an era where our power to wage warfare with atomic devices is so great, even in comparison with the recent past, that our fundamental concepts of what atomic warfare is must undergo a revolutionary change.

In the past, most of us have thought of atomic warfare in terms of intercontinental bombers striking at the great cities and industrial hearts of an enemy nation. This concept of atomic warfare, while still true, is now no longer the whole truth. It is but one kind of atomic warfare, and there is now a new, quite different kind, much less fearsome as far as noncombatants are concerned, and much more promising as a means of halting aggressors without the risk of destroying large parts of the world in the process. Because of our great technological strides, we are now entering an era when the quantities of atomic weapons available to us will be so great, and the types so varied, that we may utilize them in many different ways heretofore not possible. We can use atomic weapons tactically as well as strategically.

In the past, we in America have been inclined to attach an unusual significance to numbers as far as atomic weapons are concerned. There has not been nearly the same amount of intense curiosity about the number of artillery shells, TNT bombs or torpedoes that might be in our national stockpile. In the case of such conventional weapons, most people tend to accept the military man's evaluation of what he can do with them, and they do not necessarily wish to know how many he has — partly, at least, because they have the general impression that he has a very large number.

It is this kind of situation into which we are now moving in regard to atomic weapons.

I would like to be able to tell you how far into this new era we have advanced, but I cannot. I can say, however, that we are definitely in this new era. With each passing day our design and production progress is steadily adding to the number of situations in which atomic weapons can be tactically employed against military targets.

But where does this leave us in terms of our moral position? It leaves us in a position where we can with complete justification treat the tactical atom — divested of the awesome cloak of destruction which surrounds it in its strategic role — in the same manner as other weapons are treated. We are now at the place where we should give serious consideration to the use of an atomic weapon, provided it can be used effectively from the military standpoint and [provided] it is no more destructive than is necessary to meet the particular situation.

Our recent technological advancements constitute a message, not of despair, but of hope — hope to the millions of people throughout the world who have feared that the only two alternatives left to mankind are gradual submission to persistent Communist encroachment on the one hand or atomic obliteration on the other. We now have the third possibility of being able to bring to bear on the aggressor himself — at the place of his aggression — the fruits of our technological capabilities, and to meet the invading force in the field with a firepower that should cancel out any numerical advantage he might enjoy. Not only does this provide hope that we can stop aggression once it has started, but, insofar as those who might be contemplating aggression understand the full import of what I am trying to say, it provides a real hope for peace.

I trust that no one will find in anything I have said any assumption that a new war is inevitable. What I mean to imply is quite the opposite. No calamity is inevitable unless we steer our course toward it, or, seeing calamity, resign ourselves to destruction. We must therefore set our goals for peace, but at the same time level our sights on those who would break the peace.

*Remarks by Gordon Dean, chairman of U. S. Atomic Energy Commission at University of Southern California, Oct. 5, 1951.

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Influence of Microstructure on Creep Resistance

A paper prepared for A.S.M.'s World Metallurgical Congress, Detroit, Oct. 15 to 19, 1951.

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Some studies on the relationship between creep resistance and microstructure were reported by the present authors in *Revue de Métallurgie* for March 1950. Our material was a chromium-molybdenum steel of the analysis used for steam power plant; it was made in a basic electric furnace and killed in the ladle with $\frac{3}{4}$ lb. per ton of titanium, $3\frac{3}{4}$ lb. per ton of silicon and $\frac{3}{4}$ lb. per ton of aluminum. Its analysis was 0.12% C, 0.02% P, 0.01% S, 0.16% Si, 0.7% Mn, 0.6% Cr, 0.65% Mo, 0.03% Al and <0.010% Ti. This steel, after the usual hot work, was heat treated in nine different ways to as many different microstructures; details of treatment are given in the respective captions, Fig. 1 to 9. All specimens were etched with HNO_3 and magnified 1000 diameters.

It will be noted that two austenizing temperatures were used: 900° C. (1650° F.) for A, B, C, D and E, and 1200° C. (2190° F.) for H, K, M and P. All were tempered 25° C. above the maximum used in our creep tests (575° C.) except A, which was tempered at 675° C. (1250° F.) as in industrial practice for superheater tubes.

Creep tests were made on test pieces so heat treated. A rapid general survey was made with short tests at 25° intervals between 450 and 575° C. (840 and 1065° F.), wherein the criterion was the creep rate observed between the 25th and the 35th hour. The wide variety of creep rates at the same temperature and load for the different microstructures is shown in the following tabulation, arranged in descending creep rates at 24 kg. per sq.mm. (34,000 psi.) and 450° C. (840° F.):

Microstructure	450° C. (840° F.) and 34,000 Psi.	575° C. (1065° F.) and 10,000 Psi.
B	74*	15*
M	72.5	1.2
K	20	3.7
A	2.4	13
D	1.5	20
E	1.1	27
C	1.0	17
P	0.5	4.35
H	0.5	3.5

*Throughout this paper creep rates are expressed in units of 10^{-4}% per hr.

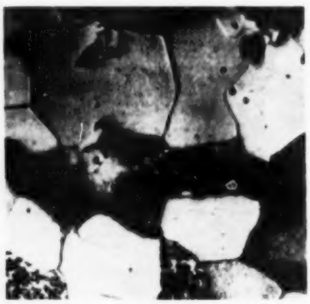


Fig. 1 — Structure A: Air Cooled From 900° C. (1650° F.) and Tempered 2 Hr. at 675° C. (1250° F.) to conform to industrial practice for superheater tubes. Ferrite grains size 8; upper bainite grain size 8; some sorbite is present

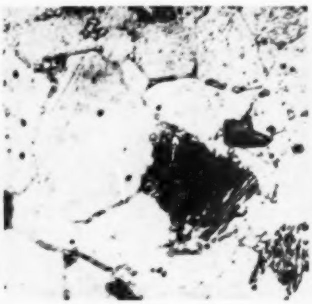


Fig. 2 — Structure B: Austenized at 900° C., Austempered 2 Hr. at 700° C. (1290° F.), Air Cooled, Tempered 2 Hr. at 600° C. (1110° F.), Air Cooled. Ferrite grains size 7 to 8; pearlite slightly spheroidized; strings of particles at boundaries

Fig. 3 — Structure C: Austenized at 900° C., Austempered 30 Min. at 300° C. (570° F.), Air Cooled, Tempered 2 Hr. at 600° C., Air Cooled. Lower bainite grain size 7 to 8 (austenite grain size 7 to 8); only a small amount of ferrite is present

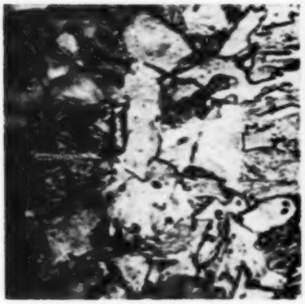


Fig. 4 — Structure D: Austenized at 900° C. (1650° F.), Austempered 30 Min. at 550° C. (1020° F.), Water Quenched, Tempered 2 Hr. at 600° C. (1110° F.), Air Cooled. Proeutectoid ferrite grains size 8 (sorbite grain size 8)

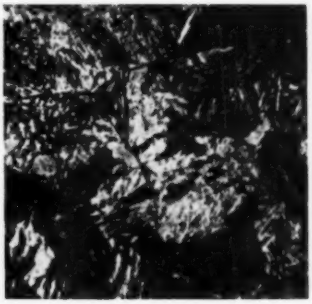


Fig. 5 — Structure E: Austenized at 900° C., Water Quenched, Tempered 2 Hr. at 600° C., Air Cooled. Sorbite (grain size 7 to 8) with a little acicular ferrite

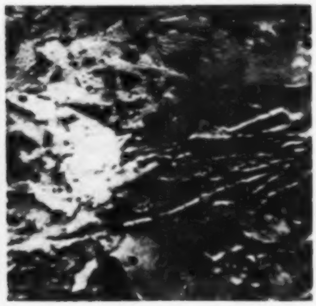


Fig. 6 — Structure H: Austenized at 1200° C. (2190° F.), Air Cooled, Tempered 2 Hr. at 600° C., Air Cooled. Bainite and sorbite in about equal parts within a ferrite matrix; austenite grain size 3 to 4

Obviously, the order of excellence is quite different in the two columns.

We determined the load at each of the six temperatures of test which would cause a creep rate of 5×10^{-4}% per hr. between the 25th and the 35th hour. The data, plotted in Fig. 10, indicate clearly that some structures, which are fairly creep resistant at low temperatures, lose their superiority at higher temperature. Furthermore the M structure (Fig. 8) of ferrite and upper bainite is nearly as good at 575 as at 450° C. One may presume that this is due to the fact that the predominant component, ferrite, was formed at a high temperature during slow cooling and consequently has a high thermal stability. Likewise the B structure, formed during austempering at 700° C., is fairly stable.

If now we plot, to logarithmic coordinates, the creep rates against the stress for tests at given temperatures (Fig. 11) we find the structures group themselves into two domains. Domain R, consisting of granular ferritic structures B, K and M, have linear relationship at both 450 and 575° C. In domain T, comprising the rest of the structures (sorbitic and bainitic), the creep rate increases at a lower rate with increasing stress in the low-stress region than in the high-stress region.

Figure 11 (right) shows that the T group is more creep resistant at 450° C., but at 575° C. (left) the change of direction of the plots shows that structures R in the R group might be preferable in ranges of low to medium stress.

A deduction from all these short-time tests is that the creep rate at lower temperatures (450 to 525° C.) decreases as the structure changes

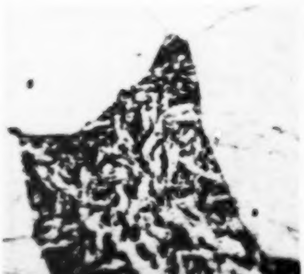


Fig. 7 — Structure K: Austenized at 1200° C. (2190° F.), Austempered 2 Hr. at 700° C. (1290° F.), Air Cooled, Tempered 2 Hr. at 600° C. (1110° F.), Air Cooled. Upper bainite grain size 5 to 6, ferrite grain size 6 to 7

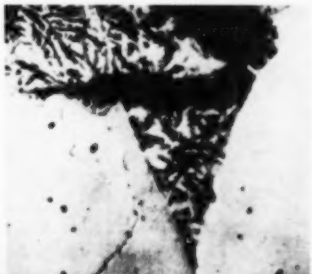


Fig. 8 — Structure M: Austenized at 1200° C., Furnace Cooled, Tempered 2 Hr. at 600° C., Air Cooled. Upper bainite grain size 4 to 5, ferrite grain size 5 to 6, bands of carbide at ferrite boundaries

Fig. 9 — Structure P: Austenized at 1200° C., Austempered 1 Hr. at 300° C. (570° F.), Air Cooled, Tempered 2 Hr. at 600° C., Air Cooled. Lower bainite grain size 3 to 4 with a little ferrite

from granular ferritic to sorbitic to bainitic. At the higher temperatures, 550 and 575° C., and at rather heavy stress, the sorbitic structures flow more rapidly than the bainitic or ferritic-bainitic structure.

LONG-TIME TESTS

The obvious criticism of the above program is that the conclusions are based on short tests of a single heat of steel. We therefore extended them by testing the same and other heats to 1000 hr. As a matter of fact, even a satisfactory long creep test is not wholly a proof that the creep rate will not accelerate later. Likewise, a long test can hardly be satisfactory for control; control requires quick appraisals. Hence we were hopeful of establishing a qualitative relation between the long and the short creep tests.

In this longer series we only tested the steels at 450 and 575° C. (840 and 1070° F.). Results are given in Tables I and II, showing creep rates at the 30th, 300th, and the 1000th hr. (V_{30}, V_{300} and V_{1000}), the total elongation at 1000 hr. (E_{1000}); in the last column is the ratio between maximum and minimum values for that line. The various microstructures are arranged according to decreasing creep rate at the 1000th hr.

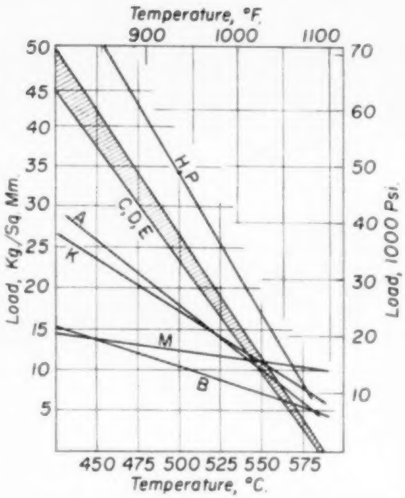


Fig. 10 — Load Required to Produce Creep at a Rate of 5×10^{-4}% per Hr. (Between 25th and 35th Hr.) at Various Temperatures for the Various Microstructures

On the whole, the tests at 450° C. fall into the same order in the various periods — that is to say, the microstructures that have creep rates on the low side at the 1000th hr. also are on the low side at the 30th and the 300th hr. (The same is true for the elongations.) As in the short-time tests, increasing creep resistance is observed as the structure goes from granular ferrite plus upper bainite or pearlite to sorbite, and it is best for the lower bainite structures. The range of excellence, maximum to minimum (last column), is hard to interpret; however, the scatter is least with the longest testing time, which indicates that the influence of microstructure is persistent, at least up to 1000 hr. at 450° C.

Stresses in kg. per sq.mm. corresponding to creep rates of 0.1×10^{-4}% per hr. at the 1000th hr. were then estimated, as well as the creep rate at the 30th hr. for the respective stresses, and are listed at the top of the opposite page.

This tabulation, showing the stress variation at a constant creep rate, arranges the structures approximately in the order shown in Table I. Likewise creep rates at the 30th hr. shown in

Table I — Creep Tests at 450° C. (840° F.)

Stress	Property	M	K	A	H	E	D				Max. ÷ Min.
15 kg. per sq.mm. (21,300 psi.)	V_{30}	5.2	0.1(?)	0.5	0.8	0.57	0.5				10
	V_{300}	1.34	0.04	0.12	0.21	0.19	0.075				20
	V_{1000}	0.46	0.11*	0.10	0.10	0.08	0.05				9
	E_{1000}	0.344	0.13	0.124	—	0.14	0.125				3
		B	M	E	A	C	H	P			
20 kg. per sq.mm. (28,400 psi.)	V_{30}	39.4	23.2	1.5	3.9	1.5	0.5	<0			80
	V_{300}	5.32	3.7	0.21	0.44	0.09	0.02	<0			250
	V_{1000}	1.95	1.4	0.15	0.05	0.07	0.01	<0			195
	E_{1000}	1.64	1.32	0.15	0.33	—	0.12	1			8
		M	B	A	D	K	C	E	P	H	
24 kg. per sq.mm. (34,000 psi.)	V_{30}	45	20	9.3	4	10	3.5	1.6	1.2	0.5	90
	V_{300}	7	2.7	1.4	1.4	1.25	0.9	0.3	0.17	0.17	41
	V_{1000}	3	0.8	0.6	0.4	0.22	0.5	0.14	0.12	0.08	37
	E_{1000}	2.4	0.7	0.37	0.5	0.65	0.24	0.19	0.15	0.18	13

*Note increasing rate with time.

the third column (except the pearlitic-ferritic structure B) are between 0.5 and 1.5, an average of 1.0×10^{-4}% per hr., which corresponds approximately to 0.1×10^{-4}% at the 1000th hr.

Creep of 0.1×10^{-4}% per Hr.

Structure	Stress	V_{30}
M	10	1.4
K	14	0.5
B	13.1	4.3
A	15	0.8
E	17.5	1.0
D	17.6	0.9
C	20.5	0.9
P	23	0.5
H	>24	—

TESTS AT 575° C.

Creep tests under three different loads are tabulated in Table II, and the arrangement from highest to lowest is generally the same at the 1000th as at the 30th hr. Under low stress the annealed structures (granular ferrites) are the more resistant, but with heavier loadings they lose their superiority, thus reaffirming the double influence of temperature and stress on any appraisal of a particular microstructure. Likewise, these annealed structures — typically the R group, namely B, K and M — have higher creep rates at 1000 hr. than at 300 hr. — a danger signal.

It is interesting to compare the above results with the preliminary tests plotted in Fig. 11. It will be noted (Table II) that structure D is one of the most creep resistant at low stress, but the least at high stress. In Fig. 11, steel D is plotted as a broken line, showing that a given increment of stress causes a smaller increase in creep at low stress (leg D_1) than at a high stress (leg D_2). Considering the propensity of group R steels to accelerate in creep at long time, we are tempted to assign real superiority to steels of group T whose log-log plot is a broken line, *provided* they are used under conditions represented by the lower leg of the plot.

Stresses for constant creep rates at 1000 hr., and the rate between 25 and 35 hr. for respective stresses, were also determined, and the listing for 575° C. and long-time tests conforms fairly well with the order presented in Table II. Also the short-time creep rates V_{30} in the third column of the tabulation on the next page are arranged in about the same sequence, large to small, as

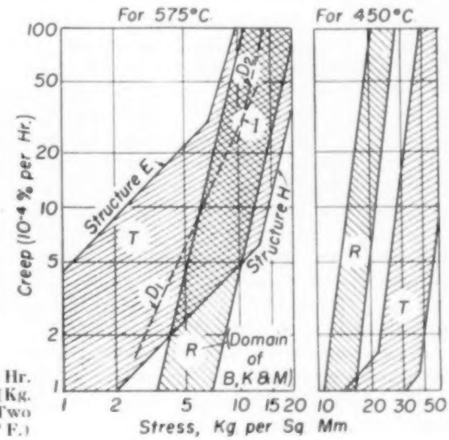


Fig. 11 — Log-Log Plot of Creep (10^{-4}% per Hr. Between 25th and 35th Hr.) Versus Load (Kg. per Sq.Mm. of the Various Structures at Two Temperatures, 575 and 450° C. (1070 and 840° F.)

Table II — Creep Tests at 575° C. (1070° F.)

Stress	Property	E	C	H	A	P	D	K	M		Max. ÷ Min.
1 kg. per sq.mm. (1425 psi.)	V_{30}	1.3	1.2	0.6	0.2	0.8	0.2	<0	0.6		6
	V_{300}	0.64	0.33	0.25	0.29	0.21	0.11	<0	0.03		21
	V_{1000}	0.43	0.27	0.15	0.09	0.09	0.06	0.05*	0.04*		8.6
	E_{1000}	0.078	0.049	0.032	0.035	0.030	0.018	0.025	0.018		4
		B	E	C	M	P	A	H			
3.5 kg. per sq.mm. (5000 psi.)	V_{30}	5.2	—	7.2	0.5	2.5	1.8	1.5			18
	V_{300}	2.5	3.45	2.42	0.58	1.1	0.77	0.7			5
	V_{1000}	2.6*	2.45	1.6	0.69*	0.4	0.20	0.20			13
	E_{1000}	0.31	0.42	0.31	0.12	0.13	0.10	0.08			5
		D	A	E	B	C	P	M	H	K	
7 kg. per sq.mm. (10,000 psi.)	V_{30}	18.5	18.5	27	5	9	5.5	2	2.7	2	13.5
	V_{300}	15	12	10.6	5.4	9.1	2.5	0.65	1.35	0.45	33
	V_{1000}	14.9	13*	12*	9.7*	7	1.4	1.4*	1.10	0.82*	18
	E_{1000}	1.54	1.36	1.58	0.80	0.84	0.23	0.16	0.21	0.17	10

*Note increasing rate with time.

in the last column, and inversely to the stress causing $0.1 \times 10^{-4}\%$ creep per hr. at 1000 hr. (second column), but they give no indication of the tendency to accelerate at 1000 hr.

Micro-structure	Creep of $0.1 \times 10^{-4}\%$ per Hr. Stress	V_{30}	Creep of $1.0 \times 10^{-4}\%$ per Hr. Stress	V_{30}
E	0.38	3.5	1.18	9.3
C	0.56	0.78	2.45	5
B	0.6	—	2.2	1.7
H	0.7	0.5	12	5.5
A	1.2	0.5	4.5	4.9
D	1.2	0.32	2.75	2.5
P	1.2	0.96	5.8	4.3
K	1.6	0.3	8	4.5
M	1.8	0.5	4.5	<1

Control Test — In view of the above, we would suggest, therefore, that a control test be made by plotting log stress versus log creep rate. Short-time tests (30 hr.) may suffice. A detailed analysis of our complete data indicates that an important consideration is stress for the point of angularity (I, Fig. 11) — if the data should give rise to a "dog-leg" line. Furthermore a "specific load" should be determined: It is that stress which causes creep at $1.0 \times 10^{-4}\%$ per hr. in the short test. (Such "specific loads" will arrange the specimens in about the same order as creep rates of $0.1 \times 10^{-4}\%$ per hr. at the 1000th hr.) The difference between the stress corresponding to point I and the "specific load" gives the safety margin of the steel for creep resistance at the test temperature.

If, as we believe, the discrimination so determined should have a valid relationship to service life, the short-time creep test would acquire interest and importance.

Further information of value would be had by determining the stress for point I and the "specific load" for various temperatures within the range of intended uses; when plotted on the same diagram, stress versus temperature, the course of the lines would forecast how the steel (and its heat treated structure) would behave in the event it were accidentally overheated.

Influence of Prior Heating — A preoccupation of all students of high-temperature alloys has been the stability of the microstructure — with good reason, for none can be considered to be in true equilibrium. In steels, structural instability may involve *(a)* change in the agglomeration of the phases or *(b)* a deterioration or change in nature of the phases.

The importance of the first consideration may be illustrated by the formula for speed of spheroidization of cementite given by Bailey and Roberts. From this it may be computed that a degree of spheroidization reached in 100 hr. at 700° C. would require 26 months at 575° C., 74 years at 500° C., and 14 centuries at 450° C.

As to the second consideration, we must remember that the carbides in a Cr-Mo alloy steel are more complex than the simple Fe_3C of cementite; in fact, we know that the higher the transformation or tempering temperature, the richer are the carbides in alloying elements. For this reason a dispersion of carbides rather than a spheroidization (growth) may occur at a given temperature. The prior carbide may dissolve and reprecipitate in a fine diffusion as one of more complex composition. Such an action may improve the creep resistance notably.

To determine some of these points we reheated test pieces of structures, shown in Fig. 1 to 9, 1000 hr. at 450° C. (840° F.), and tested them in creep at the same temperature and under a stress of 24 kg. per sq.mm. (34,000 psi.).

As shown in Table III (which should be compared with the bottom section of Table I), the order of excellence is almost unchanged. Structures of the R group (B, K and M) generally show higher creep rates, whereas the others (T group) are improved in creep resistance by the long tempering at testing temperature. Notably is this true of structure P whose creep rate at 1000 hr. is practically zero.

We advance as a hypothesis that this is due to the nature of the carbides in the T group structures. Originally formed at low temperatures, they are poor in alloying elements. Preliminary tempering for 2 hr. at 600° C. is apparently not long enough to cause as much change in their nature as the 1000 hr. at 450° C., nor to institute that fine dispersion which is normally associated with higher strength.

Table III — Creep Tests at 450° C. (840° F.) and 24 Kg. per Sq.Mm. (34,000 Psi.) on Steels Tempered 1000 Hr. at 450° C.

Property	B_{450}	M_{450}	A_{450}	D_{450}	K_{450}	C_{450}	E_{450}	H_{450}	P_{450}
V_{30}	60	57	11.8	2.8	6.7	0.5	0.3	0.2	0.1
V_{300}	8.5	7.6	2.3	0.95	0.39	0.1	0.1	0.09	0.05
V_{1000}	4.45	1.7	1.25	0.62	0.27	—	0.03	0.02	~0
E_{1000}	2.72	2.50	1.0	0.24	0.82	—	0.174	0.167	0.134

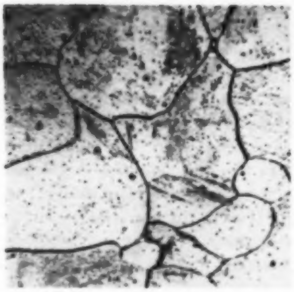


Fig. 12 — Structure B (Fig. 2) of Granular Ferrite Plus Pearlite After 100 Hr. at 700° C. Changes to Larger Grains Containing Fine Scattered Carbides With a Few Darker Areas (Possibly Concentrations of Fine Precipitates)

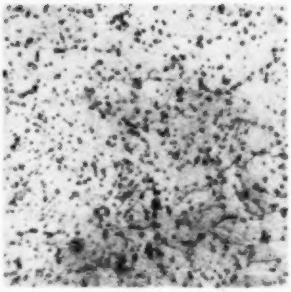


Fig. 13 — Structure E (Fig. 5) of Sorbite After 100 Hr. at 700° C. Changes. Ferrite grains with vein markings containing uniformly scattered fine carbides; there are some concentrations of particles near grain boundaries

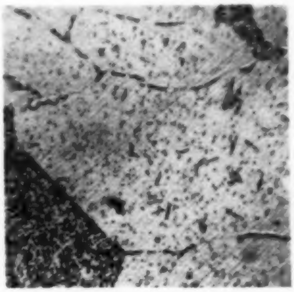


Fig. 14 — Structure M (Fig. 8) of Ferrite and Upper Bainite Grains After 100 Hr. at 700° C. The ferrite grains now contain fine scattered carbides and some carbide plates. The former bainite grains contain many scattered carbides

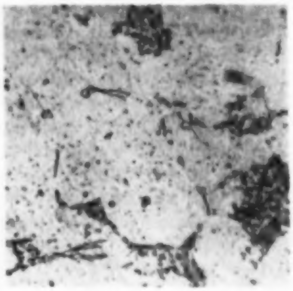


Fig. 15 — Structure P (Fig. 9) of Lower Bainite After 100 Hr. at 700° C. Larger ferrite grains contain a few scattered particles and coarse carbide stringers at the boundaries. The minor areas are rich in fine carbide particles

Carbides of the R group (B, K and M) are, on the contrary, richer in the alloying elements and have a much higher thermal stability. This is shown in Fig. 10. Changes during long stay at 450° C. should therefore primarily result in spheroidization — even at a very sluggish rate — and a loss in creep strength.

Soaking at 575° C. — Creep tests after these same structures had been reheated 1000 hr. at 575° C. (1070° F.) are shown in Table IV, and should be compared with the middle section of Table II. Creep resistance has been improved for all except H, and this general fact may be ascribed to the fine reprecipitation in all the steels at 575° C. of complex carbides stable at that temperature after solution of simpler carbides formed originally at lower temperatures.

This is probably also true of the pearlitic B structure, which is notably improved, but the hypothesis should be checked by isolating and analyzing the carbides, both before and after long tempering at 575° C.

Soaking at 700° C. — A logical extension of the above experiments is to temper representative specimens near the Ac_1 point; 100 hr. at 700° C. (1290° F.) was chosen. This changed the microstructure fundamentally, as can be seen by comparing Fig. 12, 13, 14 and 15 with Fig. 2, 5, 8 and 9 respectively. Description of the new structure is given in each caption. Bear in mind that the former magnification is 1000 diameters; in Fig. 12 to 15 it is 500. It will be noted that carbides are now fairly uniformly distributed through structures B and E and ferrite grains are large. Structures M and P now have carbide-rich zones, originating from the bainite grains.

Creep tests were made on samples with these structures. Most of them were short (35 hr.); temperatures were, as before, 450 and 575° C.; results were plotted as log stress against log creep rate at the 25th to 35th hr.

Table IV — Creep Tests at 575° C. (1070° F.) and 3.5 Kg. per Sq.Mm. (5000 Psi.) on Steels Tempered 1000 Hr. at 575° C.

Property	E_{575}	D_{575}	C_{575}	B_{575}	M_{575}	H_{575}	A_{575}	K_{575}	P_{575}
V_{30}	6	4	3	2.5	0.5	2	1.3	0.7	1.1
V_{300}	2.7	1	0.95	1.05	0.18	0.65	0.575	0.29	0.375
V_{1000}	2.2	0.95	0.65	—	0.40*	0.25	0.2	0.2	0.11
A_{1000}	0.34	0.184	0.144	—	0.059	0.094	0.087	0.062	0.066

*Note increasing rate with time.

Soaking at 700° C. made practically no change in the creep resistance at 450° C. of structures B and M of domain R (see Fig. 10 and 11). At 575° C. the curves are displaced sharply to the left, which means that the stress for a given creep rate is reduced to half its former value for structure B and to 20% of its former value for structure M.

Figure 16* shows that variation in creep rates with stress for structures E and P at both 450 and 575° F. (dashed lines) are represented by dog-leg plots. These primary structures after soaking at 700° C., when tested at either 450 or 575° F. (full lines), are represented by single straight lines. Either the flat lower slope has been eliminated or is displaced to such low creep rates as to be lost. (Some work on structure B indicates that the latter may be the true explanation.) Moreover, three of the four new lines are much to the left of the upper legs of the old lines, indicating that overheating lowers the stress for a given creep rate to about one third its former amount at the high stresses. However, at lower stresses, the situation is reversed; in that situation the stress for a given creep rate is increased to a considerable extent.

If the tests for structure M after soaking at 700° C. were plotted on Fig. 16 the straight lines would fall very close to the ones for structure P (also soaked at 700° C.) for creep tests at both 450 and 575° C. These two have carbide-rich grains (Fig. 14 and 15).

It is worthy of remark, also, that soaking at 700° C. changes the creep resistance of structure E comparatively little. However, this structure is one with high creep rates for low stress in nearly all the other work recorded here. Generally speaking, the test results on structure E do not agree with our preconceptions as to the influence of grain size, although the veining, dimly discernible within the ferrite grains, may not indicate "fine grain" in the usual sense of the word.

There is the possibility that the origin of the ferrite may have a dominating influence; E structure is the only one wherein the grains were formed during the tempering of martensite. Conditions at the boundaries of such grains may be quite different from those around ferrite grains formed at high temperatures. Furthermore, the carbide particles, also originating at low temperature, may not have reached thermodynamic equilibrium, even after 100 hr. soaking at 700° C. It is mere speculation about the structure E to say more than that it may be due to the nature of the dispersed carbides, to the nature of the ferritic matrix, to the condition at the true grain boundaries, or to some combination of these.

Finally, we believe that our tests amply prove the strong influence of microstructure on the service performance of a low-alloy, high-temperature steels. Furthermore, tests other than those described in this article have convinced us that the differences in high-temperature strength, when one microstructure is compared with another microstructure of the same steel, may be of more importance than those strength differences which arise from different chemical compositions when tested in the same structural state. This prime factor has not been given due weight in many prior investigations, and is doubtless responsible for the contradictory results that have been published.

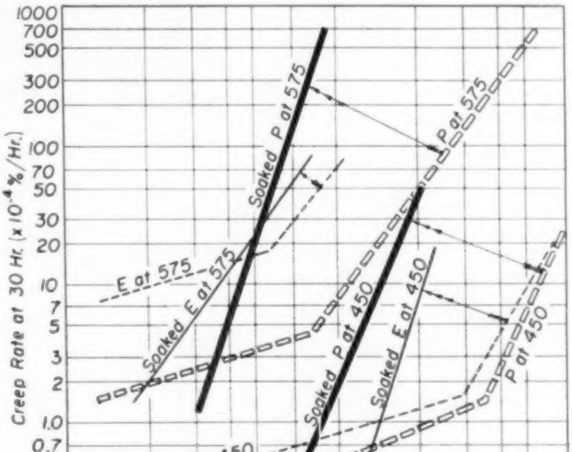


Fig. 16 — Comparison of Creep Rate Versus Stress of Structures P and E, Tested at 450 and 575° C., Both Before and After Soaking 100 Hr. at 700° C. Tests on original structures in dashed lines; tests on overheated (soaked) structures in full lines

*Note that the horizontal scale in Fig. 16 is double the vertical scale, whereas they are equal in Fig. 11.

How Accurate Is the Impact Test?

By the Metallurgical and Research Committee of the Forging Manufacturers Assoc.

The reliability of impact tests has long been a controversial subject, yet relatively little information has appeared in literature. Prompted by the question of the test's accuracy and the growing interest in impact testing of forgings, the Metallurgical and Research Committee of the Forging Manufacturers Assoc. has investigated the problem. The purpose of this phase of the investigation was to determine what variation of results is encountered among representative laboratories when the tests are conducted under usual commercial practice. Laboratories cooperating in this investigation included those of two Government agencies, one inspection agency and eleven producers of forgings. The data given in this article may be considered as a preliminary report of the findings of the Committee.

It was considered essential to minimize nonuniformity in the test bars. To obtain sufficient material from a forging to conduct the program would probably result in interbar variations owing to the greater heterogeneity of large masses of steel. Consequently, bars were machined from ⅝-in. hot rolled 4340 steel, uniformly quenched and tempered. Two tempering treatments were used, one at 700° F. which produced a hardness of Rockwell C-46 to 47, the other at 1100° F. which developed a hardness of Rockwell C-33 to 34.

Sufficient heat treated bar stock was shipped to each cooperating laboratory to prepare six specimens of each type. Any variations due to method of preparation of the test specimens are considered to be representative of what may be anticipated among responsible laboratories.

The survey included Izod and Charpy-type machines. The Charpy test was explored by using V-notch and keyhole-type test bars. The usual square V-notch bars were used in the Izod test. The test bars were broken at room temperature.

Companies cooperating in this investigation are designated in the tables and figures by a single letter. When a company had more than one plant in the program, a second designating letter is used, and when a plant laboratory had more than one impact testing machine, this is indicated numerically.

Wide Variations in Results

Results obtained are plotted in Fig. 1 and 2, the results being arranged in the order of decreasing average values. The length of the block indicates the spread between the maximum and minimum obtained by each laboratory on the different machines, the horizontal line within each block indicating the average for that machine. The major horizontal line of the graphs represents the grand average.

The average value of each machine is plotted in Fig. 3. These values are grouped according to the type of test, with both the 700° F. temper and the 1100° F. temper values indicated. The sequence of values was arbitrarily based on the 700° F. temper V-notch Charpy averages arranged in the order of decreasing values. Similar diagrams could be based upon each of the other sets of data but it is felt that these arrangements would contribute little, inasmuch as Fig. 3 fully illustrates the absence of relationship. It is apparent that high or low values in one type of test give no assurance that a machine will produce similarly high or low values in another type of test, or with the same test at a different hardness level.

In Fig. 1 and 2, the number that appears above each of the bars represents the percentage of variation in the results for the individual machine. Here again there is a lack of any consistency. Although not included in the scope of the investigation, the reported figures give an opportunity to make some further observations.

The average ranges for the three types of tests and their percentage of the average values are reported in Table I. On the basis of foot-pound value, the range of the harder material

Table I — Average Impact Values

Test Group	Temper Group	Impact Ft-lb.	Impact Range Ft-lb.	Impact Range %
V-Notch Charpy	700° F.	13.33	2.55	19.1
	1100° F.	67.74	4.26	6.3
Keyhole Charpy	700° F.	14.10	2.37	16.8
	1100° F.	35.68	3.05	8.5
V-Notch Izod	700° F.	12.97	2.73	21.1
	1100° F.	61.84	5.61	9.1

was within a few foot-pounds of the softer material. Percentage of variation in the harder material was considerably greater than in the softer material. This would indicate that reproducibility of impact values on any particular machine decreases as the impact resistance decreases.

Results of the different tests at the two hardness levels are also shown in Table I. At the higher hardness level (Rockwell C-46 to 47), the average results of both types of bars on the Charpy machine and the usual square V-notch bars on the Izod machine are about the same, with the average keyhole Charpy being highest. At the lower hardness level (Rockwell C-33 to 34), the average keyhole Charpy is lowest, being only slightly more than half of the average V-notch Charpy and Izod at the same hardness level.

PORTENT OF RESULTS

Comparing the average results of these three types of tests at the two hardness levels, and referring to Table I, the V-notch tests (Charpy and Izod) were found to be about twice as sensitive to differences in these hardness levels as was the keyhole-type test bar used on the Charpy.

Table II shows that the influence of the type of test specimen is not the same on a relatively soft or ductile steel as it is on the same steel in a harder or more brittle condition. In the more ductile material, the energy absorbed per unit of area was about the same, regardless of the type of notch. In the harder material, considerably less energy per unit area was required to break the sharp V-notch specimens than the rounded notch specimens.

Impact requirements are specified as the total energy required to break the specimen. Table II also shows the importance of the area resisting the blow in each type specimen and that it must be considered in conjunction with the type of notch used when evaluating impact sensitivity.

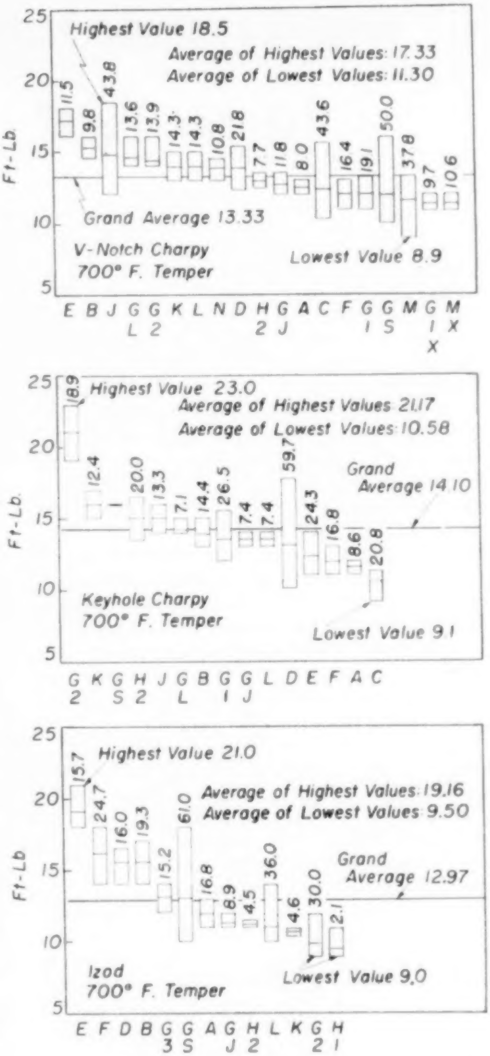
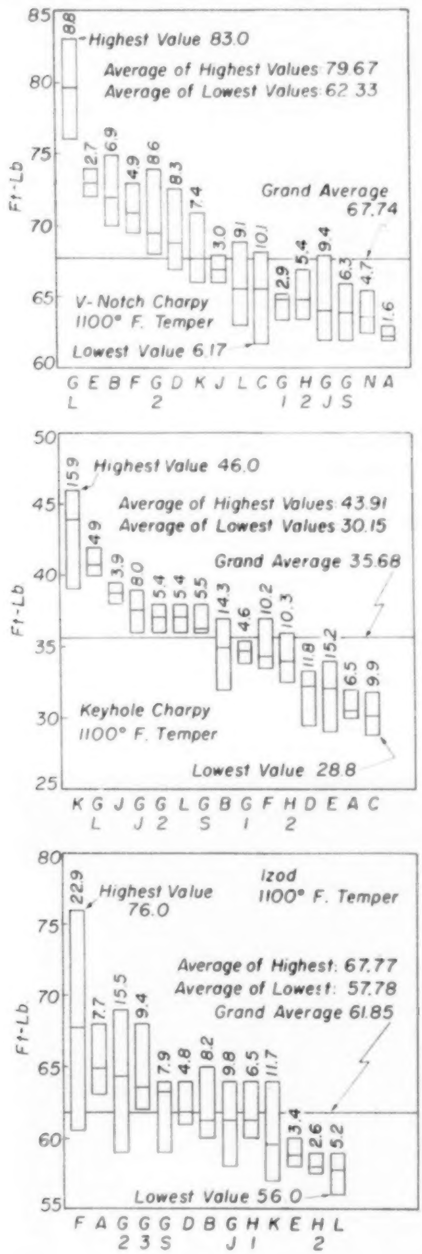


Fig. 1 — Results of V-Notch and Keyhole Charpy and Izod Tests of Material Tempered at 700° F. (Average Hardness Rockwell C-46 to 47). Extreme points of bar represent the maximum and minimum values for each test, the average designated by a horizontal line within the bar. Figure above each bar is the percentage variation on individual machines

Table II — Impact Energy Absorbed

Test Group	Resisting Area, Sq.Mm.	700° F. Temper Rockwell C-46 to 47		1100° F. Temper Rockwell C-33 to 34	
		Ft-lb.	Ft-lb./Sq.Mm.	Ft-lb.	Ft-lb./Sq.Mm.
V-Notch Charpy	80	13.33	1.67	67.74	8.46
Keyhole Charpy	50	14.10	2.82	35.68	7.14
V-Notch Izod	80	12.93	1.62	61.84	7.73

Fig. 2 — Results of Impact Tests of Material Tempered at 1100° F. (Average Hardness Rockwell C-33 to 34). Data for these tests are recorded in similar manner to those for Fig. 1



The data so far collected in this investigation permit the following deductions:

1. There is serious variation in the results from most individual machines. In other quantitative acceptance testing this would hardly be tolerated.

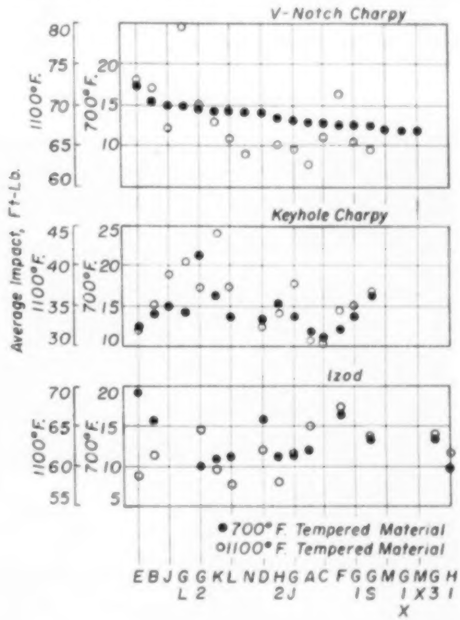
2. Even greater inconsistencies were found among the average results for each of the machines.

3. The machines do not give consistently high or consistently low results on all types of tests nor on one type of test at different hardness levels.

4. The reproducibility of impact test results decreases as the impact resistance decreases when using the standard-type machines and conducting the tests in the present normal manner. This suggests that consideration might be given to the use of machines of different capacities. Possibly, the use of a low capacity machine might show similar or comparable percentage variation when testing low impact material as standard machines have shown when testing the higher impact materials. However, this possibility would have to be similarly investigated before greater dependence could be placed on lower capacity machines.

5. The behavior of the steel treated to different hardness levels was not the same in the various types of tests. The keyhole tests *(Cont. on p. 176)*

Fig. 3 — Plot of Average Value of Each Test Performed by Individual Machine Does Not Show Any Relationship Between the Temperature Groups for the Same Type of Test Nor for Other Types of Test



Simple Tester for Hardness of Hot Materials

By R. F. Domagala and W. R. Johnson
Armour Research Foundation
Chicago

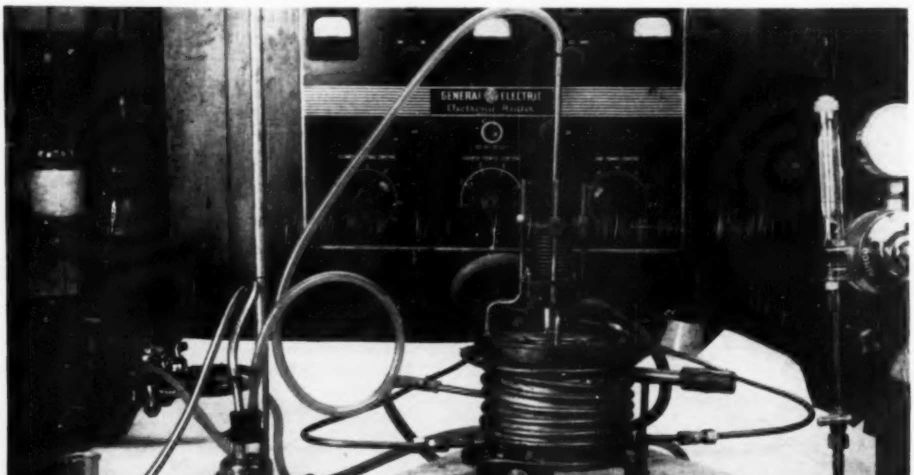
A RAPID, REPRODUCIBLE METHOD for testing hot hardness of materials at temperatures approaching their melting points has recently been developed for the Air Matériel Command at the Armour Research Foundation of Illinois Institute of Technology. The inexpensive equipment, induction heated, is drawn in cross section on the opposite page. The specimen is heated by contact with the molybdenum anvil, which in turn is heated by a ⅛-in. coil of water-cooled, copper tubing carrying high-frequency currents. Copper radiation shields minimize heat losses, while water flowing through copper tubing encircling the body of the tester keeps the shell cool.

A natural octahedral diamond crystal was chosen as the indenter because of its low cost and relative ease of mounting for use at elevated temperatures. The diamond was pressed into a small molybdenum block and swaged in place. The block was then machined to size, using the diamond tip orientation as the locating point. The holder was then secured to a ¼-in. sapphire rod by a piece of molybdenum wire passing through the holder and two notches on the sapphire rod. This is illustrated in detail alongside the general cross section.

The loading mechanism consists of a 1-in. stainless steel bellows, 1½ in. long, with silver soldered end plates. A steel tube enters the top plate, silver soldered, through which pressure is transmitted. During operation of a series of tests, the top plate is clamped to the cover by two nuts on each of three support rods. The bottom plate of the bellows rests on the sapphire rod carrying the indenter, which in turn rests upon the specimen; thus, upward movement of the bellows is prevented and the applied load is transmitted.

Loading is simply done. A length of Tygon tubing leads from the stainless bellows to a mercury trap. This trap is nothing but a stout jar closed with a rubber stopper, wired down.

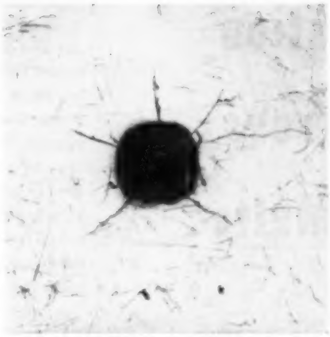
General Arrangement of Equipment. Furnace in center foreground, heating controls at rear, atmosphere equipment at right, pressure device at left



and half filled with mercury, half with water. Two glass tubes pass through the rubber stopper, one short one reaching into the water, the other long enough to reach well into the mercury underneath. The shorter tube is joined to the Tygon tubing above mentioned, leading to the stainless bellows. This length of tubing is also completely filled with water.

The longer glass tube is connected with flexible tubing to a small mercury reservoir (extreme left in half-tone) which can be raised and lowered. In this way pressure can be increased or decreased at will, the mercury pressure being transmitted through the water to the stainless steel bellows. The presence of water in the loading mechanism prevents contact of mercury and metal at all points. In this manner loads on the indenter of any desired size up to 15 or 20 lb. can be obtained.

The hot chamber is designed for use under a slight positive pressure of inert gas. A replaceable thermocouple situated well up into the head of the anvil gives a close approximation of specimen's temperature. Since the sapphire rod is situated off-center with respect to the anvil, and the anvil can be revolved by thumb nut and bevel gear, several indentations at one temperature or at a series of temperatures can be made quickly and easily in unbroken succession. Specimens up to about 1 in. in diameter and ¾ in. thick may be tested. Temperatures up to 2400° F. (1315° C.) have been reached with little difficulty, while higher temperatures could probably be attained if desired. Some of the tests that were made on silicon and molybdenum, and on vanadium silicide at temperatures between 1000 and 2400° F. are listed in the table.

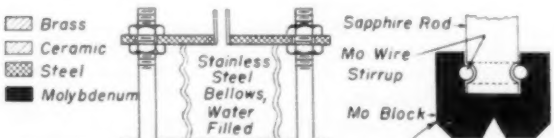


A Hardness Indentation in Silicon at 1525° F. (830° C.) at 75 ×

Hardness of Hot Substances

Temperature	Molybdenum	Silicon	VSi_2
1060° F.	11.8	25.0 (?)	
1500			35.9
1535	10.6	21.3	
1800	8.5	12.2	
2000			17.2
2045	8.3	9.9	
2230		8.2	
2400		7.1	

Hardness values are reported in K/mm.² where K is a constant depending upon the geometry of the indenter and the load, while mm. is the average width of the indentation measured with a filar micrometer. An indentation made in silicon at 1525° F. (830° C.) is also shown herewith, magnified 75 diameters. Since the indenter is a natural diamond crystal of unique geometry, comparisons with other hardness scales cannot be made but it does furnish a reliable means of obtaining comparative hardness of hot materials.



General Cross-Sectional Drawing of Hot Hardness Tester and Detail of Indenter and Its Mounting

Contamination of Nonferrous Foundry Melts

By A. L. Simmons
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In the operation of nonferrous foundries, particularly when working to specifications and on a continuous basis on one composition, accidental contamination of a charge can be very serious. This affects not only the particular charge, but also subsequent charges because return scrap is contaminated.

There are ways of predicting mathematically the future course of such contamination. Two examples of such determinations will be given.

Accidental Contamination

An instance occurred where ingots of cartridge brass (70% Cu, 30% Zn) were cast from a charge having a high proportion of cases returned from battlefields. Unfortunately, there were mixed in with the brass cases a few of steel which had been zinc plated and chromated. In their dirty and stained condition, the appearance of the latter was almost identical with tarnished brass cases; consequently some found their way into the brass charges.

The iron content of the ingots jumped from a normal 0.025 to 0.030% up to 1.5%, the specification requirement being 0.05% maximum. The ingots were spectrographically analyzed each day so that the trouble was picked up fairly quickly and the cause of it, the steel cases, soon discovered. Thereafter, close visual inspection, and testing with a magnet in doubtful cases, eliminated the trouble. However, there were left on hand about 90 ingots with excessive iron content and the question was, what to do with them?

Two courses were open:

1. To use them in the foundry for remelting, diluted with metal of sufficiently low iron content to bring the average within the desired specification range.

2. To sell them to a scrap dealer (and thereby let somebody else have the trouble).

Method 2 was the least desirable, as a considerable monetary loss would be involved. The best plan was to use as much of this metal as possible, but to spend a minimum of money on preparing it for remelting; in other words, the most economical way of handling the material was to remelt without cutting as many of the ingots as could be used in foundry charges and sell the balance.

The following methods were used to determine a suitable practice for the foundry charges:

The furnace in normal operation holds sufficient metal for five ingots of the size under consideration. Since the usual iron content is about 0.03% and the specification limit is 0.05%, the maximum iron content M of the metal which can be added in an ingot-weight unit is given by

$$(4 \times 0.03) + (1 \times M) = (5 \times 0.05)$$
$$\text{Hence } M = 0.13\%$$

For safety let us limit M to 0.10% and sell all ingots having iron above this limit.

The next point to consider is how frequently can a whole ingot be added without bringing the metal out of specification? Assume the furnace full of metal of normal iron content. One ingot is poured and replaced by an ingot of high iron content. When this is melted another ingot is poured from the mixture and this is replaced with metal of normal iron content. Then another ingot is poured, and is replaced with metal of normal iron content. This is continued until the iron content of the metal in the furnace has dropped to a value low enough to permit adding another ingot of high iron content without exceeding the specification limit, or, alternatively, without increasing the iron content of the scrap in circulation to a high figure.

This problem was tackled as follows:

Let f be the normal or usual iron content, and F that of the mixture after adding the first ingot high in iron. When another ingot is poured and replaced with metal of normal composition, the iron content of the metal in the furnace will be:

$$\frac{4}{5} \cdot F + \frac{1}{5} \cdot f$$

When this procedure is carried out n times the iron content will be

$$\frac{4^n}{5^n} \cdot F + \frac{4^{n-1}}{5^n} \cdot f + \frac{4^{n-2}}{5^{n-1}} \cdot f + \ldots \frac{4}{5^2} \cdot f + \frac{1}{5} \cdot f$$

or $$\frac{4^n}{5^n} \cdot F + f \cdot \sum_1^n \frac{4^{n-1}}{5^n}$$

The last term is a geometrical progression of the form $a + ar + ar^2 + \ldots\ldots\ldots + ar^{n-1}$, where $a = 1/5$, $r = 4/5$, and the sum of n terms is given by

$$a \cdot \frac{1 - r^n}{1 - r} \qquad \text{therefore, } \sum_1^n \frac{4^{n-1}}{5^n} = 1 - \left(\frac{4}{5}\right)^n$$

Hence, the iron content after n ingots have been poured and replaced with metal of normal composition is

$$\left(\frac{4}{5}\right)^n \cdot F + f \cdot \left[1 - \left(\frac{4}{5}\right)^n\right] = f + \left(\frac{4}{5}\right)^n \cdot (F - f)$$

In this case $f = 0.03\%$, and F is given by

$$\left(\frac{4}{5} \times 0.03\right) + \left(\frac{1}{5} \times 0.1\right) = 0.044\%$$

Hence, the iron content after n ingots is:

$$0.03 + \left(\frac{4}{5}\right)^n \times 0.014$$

To bring this to 0.03%, the normal iron content, the last term must be zero — that is, n equals infinity. In practical application this is not feasible, so an approach must be made to this ultimate desired value.

Under the conditions of operation, 17 ingots were cast per shift. By putting $n = 17$ we have

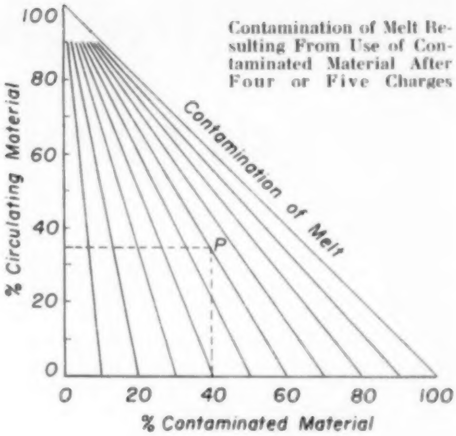
$$0.03 + \left(\frac{4}{5}\right)^{17} \times 0.014 = 0.0303\%$$

Therefore, if one ingot was added per shift, and at the same time each shift, the iron content would have dropped to practically normal by the time the next was added, and at no time would the specification maximum be exceeded.

REGULAR USE OF CONTAMINATED MATERIAL

It is desired to determine what build-up in impurities will occur in cast ingots, when the foundry charge consists of contaminated material, of circulating scrap derived from the charges and of uncontaminated material.

The treatment given here is somewhat similar to that of Smith (*Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 152, discussion to paper on p. 127). Let A be the fraction of the charge composed of contaminated material. Let X be the content of contamination in this material. Let B be the fraction of the charge composed of circulating scrap derived from previous melts. The charge proportions for the first melt will be A and $1 - A$, and for the successive melts the proportions will be A, B and $1 - (A + B)$. Total contamination of the first melt will be $A \cdot X$, of the second melt it will be $A(1 + B)X$, of the third it is $A(1 + B + B^2)X$; therefore the contamination after n melts is $A(1 + B + B^2 + \ldots\ldots + B^{n-1})$ times that in the contaminated material used in making up the charge. This expression approaches, for large values of n and fractional values of B, a limiting value $A/(1 - B)$; in practice, this limit is very nearly reached after 4 or 5 melts. This function has been plotted in percentages in the accompanying graph. The following example illustrates its use.



Contamination of Melt Resulting From Use of Contaminated Material After Four or Five Charges

Suppose it is desired to produce 70-30 brass for hot rolling. It is known that the lead content must be limited to 0.015% maximum to insure freedom from cracking during hot rolling. A supply of contaminated material containing 0.025% lead is available, and it is known that to avoid accumulation of circulating scrap this scrap must constitute 35% of the foundry charge.

The problem becomes: What proportion of contaminated material must be used in conjunction with 35% of circulating scrap to obtain a proportional contamination of the melt equal to $0.015/0.025 \times 100 = 60\%$. (The term "proportional contamination" means the ratio of desired maximum impurity of the melt to actual impurity of the contaminated material.

In the graph a horizontal line drawn from the ordinate at 35% circulating material to intersect the 60% contamination line at P indicates that a value of 39% contaminated material will give this condition. Hence the charge composition will be: 26% clean material, 35% circulating scrap, 39% contaminated material.

Surface Treatment for Cold Extrusion

Fig. 1 — Typical Example of Forward Cold Extrusion. The starting billet is reduced in cross-sectional area about 85% with a single press operation. Courtesy of the Pennsylvania Salt Mfg. Co.

By the late Adolph Bregman
Consulting Engineer
New York City
Consulting Editor for Metal Progress

An important discovery of the last few years in the working of metals is that steel is a plastic material at room temperature.

This knowledge was born out of Germany's need during the last war for higher and more rapid production of war materials — a difficult task in face of the critical shortages in raw goods and equipment which resulted from the Allied blockade. The Germans turned to cold extrusion in an effort to conserve steel and reduce the labor involved in hot forming. They were successful in extruding carbon steel such as our S.A.E. 1010, achieving cold reductions of 70 to 75% in cross-sectional area.

After the war, this method of operation was picked up by the American Technical Industrial Intelligence Committee and the data made available to American industry. As a result, the cold extrusion of steel shells was investigated and is now being successfully practiced here. The advantages claimed for it over hot forging include reduction in steel requirements, reduction or elimination of heat treatment and machining operations, more uniform mechanical properties and improved surface of final product.

The most fruitful contribution to American practice in this field was the work done at the Heintz Manufacturing Co., Philadelphia, on an Ordnance research project.* As stated in the letter of transmittal accompanying their report, the results were significant.

The first consideration in undertaking the cold extrusion of steel was that in addition to the use of the proper material for dies, it would be necessary to treat the surface of the steel to provide lubrication. For that reason, the requirement of the research was to develop: "Surface treatments, including both boundary lubrication and semiliquid lubrications; this to refer to chemicals as well as applied research."

Details were set forth in the original investigation, known as "Cold Shaping of Steel — Summary Report, July 1947, Contract W-36-034-ORD-7603", pertaining to preparatory calculations, planning of procedures, processing of steels, together with the general remarks concerning cold shaping of steel by extrusion.

It was found that the cold shaping technique demanded the use of a crystalline metal phosphate coating with a lubricant having a film sufficiently durable to withstand the compression which forced the steel through the extrusion die. The lubricant film was required to remain unbroken between the work and the tools in order to prevent galling, scoring and pickup. This coating was produced by treating the steel with an acid phosphate solution by dipping or spraying and adding a compatible lubricant to the coating.

The program of work included, first, the determination of the apparent coefficient of friction within the pressure range of 2500 to 200,000 psi. using emulsified sulphonated tallow as a lubricant on steel coated with various phosphates; the effect of various lubricants on standard zinc phosphate coated steel in the low and high pressure range; the effect of lubricants on uncoated steel in the low and high pressure range; the effect of coating and lubricant on cold reduction under tension (drawing); and the effect of coating and lubricant on cold reduction under compression (extrusion).

The research also developed exact informa-

*Surface Treatment Research in Conjunction With the Cold Shaping of Steel"; Sub-Project ORD TB-4-61C; Contract M-36-034-ORD-7654.

Fig. 2 — Backward Cold Extrusion Employed as the First Step in Forming a Tubular Body. Cut at top shows a steel billet after Foscoat treatment and cut at right shows the cup formed in a single press operation. Alternate method would probably be to hot forge or hot upset a billet of about twice this starting size and then machine to finish size. Illustrations courtesy of the Pennsylvania Salt Mfg. Co.

tion regarding the most economical lubricant. The best coating (without which the heavy extrusion of steel is impossible) was found to be the conventional zinc phosphate material.

This simplification of technique and working directions made possible the extrusion of a billet in a single operation to a reduction in cross-sectional area of 85%, the greatest by far ever reported. A condensed abstract of the Heintz report follows.

The lubricants used were of three types:

1. Dilute emulsion — a highly diluted soap emulsion not exceeding 5% concentration of soap, plus animal or vegetable oils or fats.

2. Commercial — a more concentrated soap emulsion containing animal or vegetable oils or fats, pigmented or nonpigmented. These were applied in the "as-received" condition.

3. Dry — such as the dry metal stearates.

EFFECT OF LUBRICANTS ON ZINC PHOSPHATE

While zinc phosphate coated steel alone, that is, without the addition of any other lubricant, is known to have a lower coefficient of friction than uncoated steel without lubricant, addition of a suitable lubricant to the phosphate coating lowers the coefficient of friction still further. Under the simplest or "normal" conditions of applying a dilute emulsion type of lubricant, that is, short immersion at room temperature, emulsified sulphonated tallow was found to be the best of eight emulsified lubricants tested. Included in the dilute emulsion group is lard oil which seemed to have competing qualities by reason of its availability and low cost.

Under the same conditions of application, lard oil (of the type containing free fatty acids up to 15%) was found to give better results than a similar oil with lower fatty acid content, such as 2.7%. Additives which would be readily adsorbed on a metal surface improved the lubricant quality of high fatty acid lard oil to nearly that of sulphonated tallow.

An important factor demonstrated in this investigation is that all lubricants tested were greatly increased in effectiveness by their application at elevated temperature and for a longer immersion time. In the lower pressure range under these conditions of time and temperature, the coefficient of friction was only a fraction of that experienced with lubricants applied under "normal" conditions. At higher pressures the differences, although not so great, were nevertheless noteworthy. The lubricant value of *all*

types tested was so greatly improved by their use at higher temperature and for longer immersion time that this method of application merits serious consideration.

For the maximum reduction of friction in cold working steel, emulsified tallow applied to a zinc phosphate coated surface at 70° C. (158° F.) by immersion for 1 hr. was found best. Commercial and solid lubricants did not approach these results.

Using the three types of lubricants on phosphate coated and uncoated surfaces, it was found that the phosphate coated surface always gave a lower coefficient of friction.

It was demonstrated that of the metal phosphate coatings tried, a zinc phosphate coating gives the lowest coefficient of friction. This is of special interest since phosphate coating is the cheapest and most practical to apply.

CONCLUSIONS

The advantage of a zinc phosphate coating over the other types of phosphate coatings is relatively less in the higher pressure range but of a useful magnitude. At lower pressure ranges, the reduction of friction by the use of phosphate coatings and lubricant is relatively a less important factor.

Testing of the three groups of lubricants in a conventional drawing operation has demonstrated that the dilute emulsion type and the solid dry type were superior to the more costly commercial types. While little difference was noted in the results for the dilute emulsion type and the solid dry type, the former is the cheaper and much easier to apply.

The program pertaining to the study of the effect of coating and lubricant in cold extrusion (reduction performed under compression) revealed that uncoated material could not be used for such an operation. Phosphate coating of a thickness of at least one gram per square foot in combination with a dilute emulsion-type lubricant produced the best frictional conditions and also eliminated pickup on the work.

For the cold extrusion of steel, it is necessary to apply a coating that is resistant to temperatures of 750 to 1100° F. and is of sufficient thickness to insure complete separation of the sliding metal surfaces. Zinc phosphate coating meets these requirements.

High, fatty acid lubricants containing polar groups, which enhance their adsorbability, are very effective in combination with phosphate coatings. Such lubricants may be applied in the solid or liquid form, the latter either as a diluted or concentrated soap emulsion. The liquid lubricants, due to their chemical composition, react chemically with a phosphate coating to form a water-insoluble lubricant film that is well interlocked with the coating. It is the effectiveness of this combination of the lubricant film with the phosphate coating that determines the degree of friction reduction.

Since the appearance of the first report, cold extrusion at Heintz has been successfully applied to steels of higher carbon, and to a series of alloy steels containing chromium, nickel, manganese and some molybdenum. Extrusions can be made in solid or tubular shapes, with fine finish, close tolerances and high physical properties. Extrusion can replace forging and casting in many instances, eliminating machining for size or finish. Another example of its profitable application is in the manufacture of large screw machine products where scrap is said to be almost negligible due to the elimination of machining, the stock yielding up to 90% product of the original weight.

A smooth, high finish with good stress resistance is obtained, making possible additional savings in metal by designing parts in thinner sections than before. This extrusion principle has been applied with great success to ammunition components, and is readily applicable to industrial parts.

Coincidentally, manufacturers of materials for metal treatment have developed improved formulations applicable to this type of operation. A process which, it is said, greatly extends lubrication limits in the cold working of steel has been announced by the Pennsylvania Salt Mfg. Co., Philadelphia. The Pennsalt "Foscoat" process con-

Fig. 3 — First Operation in the Extrusion of This Button of Low Alloy Steel Is a Combination of Coining and Blanking, Followed by One Extrusion to Form the Gear. Photograph courtesy of the Parker Rust Proof Co.

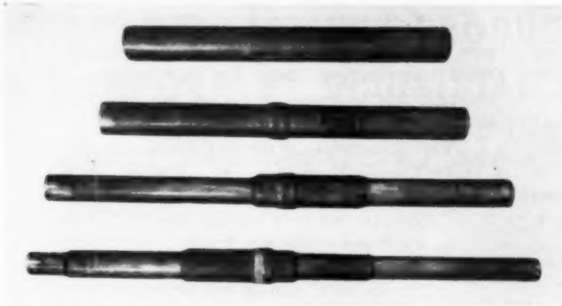


Fig. 4 — Automobile Transmission Drive Shaft Treated With Bonderite Coating and Lubricant Is Cold Formed at Molloy Mfg. Co., Detroit. Courtesy of the Parker Rust Proof Co.

sists of compatible cleaning, pickling and application — by immersion, flooding or spraying — of a new phosphate coating and a lubricant (Foslube) to steel, to produce a heat resistant lubricating surface with exceptional adherence under the most severe working conditions. This material is the result of joint research conducted by Pennsalt and Heintz and has been successfully demonstrated (Fig. 1, for example) in cold extrusion. The next step, according to Heintz engineers, awaits availability of presses of sufficient size (travel) to take advantage of the raised lubrication limits.

The lubricant is also useful for tube drawing, wire drawing, deep drawing (ironing), deep stamping, cold heading and similar cold working operations. In wet drawing fine steel wire, for example, the Foscoat process is said to have effected a 40% increase in the rate of production while die life was increased 2½ times. In dry drawing of triangular and square shapes from round wire stock, one application permitted drawing to finished shape without the intermediate anneals and recoating required in previous processes.

In deep drawing (ironing) of steel cartridge cases, 80% reductions in wall thickness were possible with a single coating treatment without intermediate annealing — a 100% improvement over conventional practice. Over-all reductions of 80% were achieved in rod-pulled tube drawing with a single application of the Foscoat for a 60% improvement over the previous method.

Another material available for this purpose is Bonderite produced by the Parker Rust Proof Co., Detroit. This is recommended for use with Bonderlube, the dry Parker lubricant, for forming steel by cold drawing and extrusion. It is applied by all conventional methods and is used in the production of a wide variety of products, such as cartridge cases, tubing, CO_2 flasks, automobile drive shafts, shock absorber tubes, gears and stud bolts. It is also in service for cold forming stainless steel and aluminum, and is under experimental work on copper alloys.

Correspondence

$CaCN_2$ — a Useful Ladle Addition

STAMFORD, CONN.

Every now and then a new process, technique, development or technological advancement escapes the knowledge of those who it is assumed should be most familiar with it. This is brought to mind by reading the published version of a panel discussion at the Western Metal Congress in the June issue of *Metal Progress*. I refer, specifically, to the statement that "nitrogen isn't something which you throw into the ladle in steelmaking; it is something that is always present".

Actually, the quoted words are far from the truth. Although there is always some nitrogen in steel, nitrogen is often added to obtain certain desirable characteristics. Such additions are made to the ladle or, at times, to the runner.

It has been known for over ten years that the nitrogen content of steel can be increased by the addition of calcium cyanamide, $CaCN_2$. In more recent years, it has become known to a large segment of the steel industry as a practical, inexpensive and efficient source of nitrogen, and has caused the nitrogen-bearing steels to be re-examined by many producers. Operating data show that an average of 20% of the available nitrogen is recovered, so that about 0.45 lb. of commercial calcium cyanamide per ton of steel is required for an increase of 0.001% of nitrogen. Used in this way, numerous carloads of cyanamide are consumed annually by the steel industry.

Probably the largest application is for tinplate where it causes increased temper hardness with less cold-reduction. In general, high nitro-

gen contents are often desirable where increased stiffness is required in thin sections. Another important application is in the production of synthetic bessemer steel. It is anticipated that many more applications for high-nitrogen steels will be indicated when the role of nitrogen in steel is more completely evaluated — for example, with respect to hardenability, corrosion, aging and mechanical properties.

A. M. WHITE
American Cyanamid Co.

Editor's Comments

Statements made in an animated discussion, such as the one at the Western Metal Congress, are likely to lack the precision and scope of a document written with deliberation. Those who will re-read the original report on pages 825 and 826, *Metal Progress* for June, will find that the "experts" were considering the various elements as they affected the quench hardening ("hardenability") of steel rather than any influence on work hardening or age hardening. There was no disparagement of the role of nitrogen — quite the opposite.

Effect of Titanium on Gray Iron

NIAGARA FALLS, N. Y.

So much has been written about titanium in the past six months that it has created an interest on the part of all metal users concerning the application and properties of this metal. Since a foundryman's inquisitive nature follows the same line as a metallurgist's, I believe this is the reason Mr. J. Ochsner, chief metallurgist, Crouse-Hinds Co., Syracuse, N. Y., sent two ⅞-in. round bars of gray cast iron, one untreated and one treated with 0.15% titanium, to Titanium Alloy Mfg. Co., Niagara Falls, N. Y., for examination of physical properties and microconstituents. Each bar had 3.36% carbon, 2.87% silicon.

Macroscopic examination of the treated bar indicated good distribution of fine graphite* plus some TiC formation. Microscopically each bar shows considerable steadite (indicating presence of high phosphorus) with a matrix of ferrite and pearlite plus graphite flakes. The untreated bar had a greater ferrite to pearlite ratio plus longer graphite flakes. The typical pale angular crystals of titanium carbide are a third contributing factor for the increase in strength and hardness as found by tensile and Brinell tests.

Test data obtained are as follows:

1. Tensile Strength
   Untreated bar with one notch, 29,400 psi.
   Treated bar with two notches, 35,700 psi.
2. Hardness (3000-Kg. Load)
   Untreated bar, Brinell 163
   Treated bar, Brinell 185

This variance in strength, notch sensitivity, and hardness is of the magnitude expected for a 0.15% titanium addition. Other properties which should be influenced by the graphitizing effect of titanium are machinability, heat resistance and corrosion resistance. These properties are improved along with strength and hardness when finer graphite is produced.

D. W. MCDOWELL, JR.
Titanium Alloy Mfg. Co.

*The pronounced effect of titanium on graphite size and distribution is shown in micrographs by George Comstock which appeared in Titanium Alloy Mfg. Co.'s publication, "The Effect of Titanium on Cast Iron".

Progress in Corrosion Prevention

TEDDINGTON, MIDDLESEX, ENGLAND

Since 1945, outstanding progress has been made in the treatment of the corrosive environment. In immersed corrosion, the use of corrosion inhibitors has been long established, both for acid conditions (for example, in pickling solutions for the removal of scale without attack on the underlying steel) and in neutral solutions and natural waters. However, some of the most efficient corrosion inhibitors — such as sodium chromate — for the latter purpose have the disadvantage of giving rise to marked localized attack, if the amount added falls just below that needed for complete protection.

Investigations at Britain's Chemical Research Laboratory at Teddington, Middlesex, have revealed the valuable corrosion-inhibitive properties of sodium benzoate. This is free from the objection of localized corrosion if insufficient inhibitor is added, although a stronger concentration is needed for protection than with the chromates. It has the further advantage of compatibility with organic substances so that it may be added to antifreeze solutions of glycol and glycerin in which it contributes to the freezing point depression in proportion to the amount that is added. Impregnated in paper, it is used extensively for the wrapping of machined steel surfaces for storage or transport; under conditions of high relative humidity intermittently

(Correspondence continued on p. 81)

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Michiana Products Corp., Michigan City, Ind.
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Montague Machine Co., Turners Falls, Mass.
Moran Flexible Joint Co., Inc., Louisville 2, Ky.
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Peru Foundry Company, Peru, Indiana
Pusey & Jones Corp., The, Wilmington 99, Del.
Reda Pump Co., Bartlesville, Okla.
Richmond Foundry & Mfg. Co., Inc., The Richmond 20, Va.
Ross-Meehan Foundries, Chattanooga 1, Tenn.
St. Paul Foundry & Mfg. Co., St. Paul 3, Minn.
Shenango-Penn Mold Co., Dover, Ohio
Standard Brass & Mfg. Co., Port Arthur, Texas
Stanley Foundries, Huntington Park, Calif.
Sterling Foundry Co., The, Wellington, Ohio
Taylor & Fenn Co., The, Hartford 1, Conn.
Texaloy Foundry Co., San Antonio 3, Texas
Thomas Foundries, Inc., Birmingham 1, Alabama
Trinity Valley Iron & Steel Co., Fort Worth, Texas
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Zenith Foundry Co., West Allis 14, Wis.

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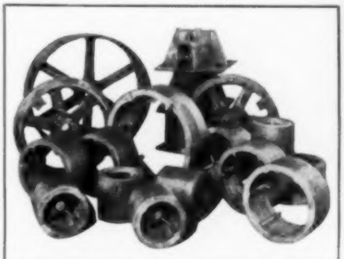
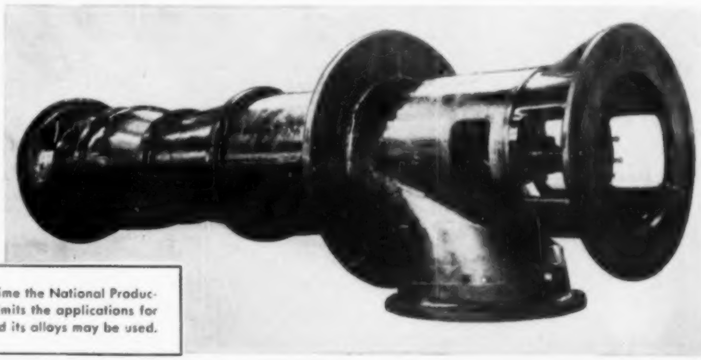
Light Castings . . . These piston rings are produced in Ni-Resist for engines used in corrosive service.



Medium Castings . . . Free from tendencies to corrode, comminutor parts cast in Ni-Resist lengthen life of sewage disposal equipment.

Heavy Castings . . . Casing, outer column and discharge head of this 14-ton pump are cast in Ni-Resist for resistance to salt water and other corrosive media.



EMBLEM OF INCO SERVICE — TRADE MARK

At the present time the National Production Authority limits the applications for which nickel and its alloys may be used.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Properties of Nimonic* Alloys

Chemical Composition

	75†	F† and CF‡	80,* C† and CC‡	80A*	90,* B† and CB‡	D†
Nickel	80 *(a)*	72 *(a)*	80 *(a)*	80 *(a)*	62 *(a)*	37 *(a)*
Chromium	18 to 21	18 to 21	18 to 21	18 to 21	18 to 21	18 *(a)*
Cobalt	—	—	<2.0	<2.0	15 to 21	
Iron	<5.0	5 to 11	<5.0	<5.0	<5.0	Remainder
Titanium	0.2 to 0.6	0.2 to 0.6	1.8 to 2.7	1.8 to 2.7	1.8 to 2.7	
Aluminum	—	—	0.5 to 1.8	0.5 to 1.8	0.8 to 1.8	
Carbon	0.08 to 0.15	0.08 to 0.15	<0.1	<0.1	<0.1	
Silicon	<1.0	<1.0	<1.0	<1.0	<1.5	2 *(a)*
Manganese	<1.0	<1.0	<1.0	<1.0	<1.0	
Copper	<0.5	<0.5	—	—	—	

Physical Properties

	75, F	80, 80A, C	90, B	D
Specific gravity	8.35	8.2 to 8.25	8.27	8.53
Specific heat *(b)*				
20 to 100° C.	0.11	0.103		
20 to 900° C.		0.128		
Thermal conductivity *(b)*				
At 100 °C.	0.032	0.029	0.030	0.034
At 900° C.	0.071	0.066	0.069	0.075
Thermal expansion *(c)*				
20 to 100° C.	12.2	11.9	11.6	14.2
20 to 500° C.	14.1	13.7	13.7	16.2
20 to 700° C.	15.4	14.5	15.0	15.5
20 to 900° C.	16.0	15.8	17.0	
Electrical resistivity *(d)*	109	124	115	108

*Nimonic 80, 80A and 90 are wrought alloys which meet specifications D.T.D. 725, 736 and 747, respectively, containing creep clauses. *"Nimonic" is a registered trade-mark owned by Mond Nickel Co., Ltd., London, England.*

Recommended Heat Treatments

Nimonic 75 and F are not usually given solution or aging treatments. Recommended anneal is at 1650 to 1825° F.

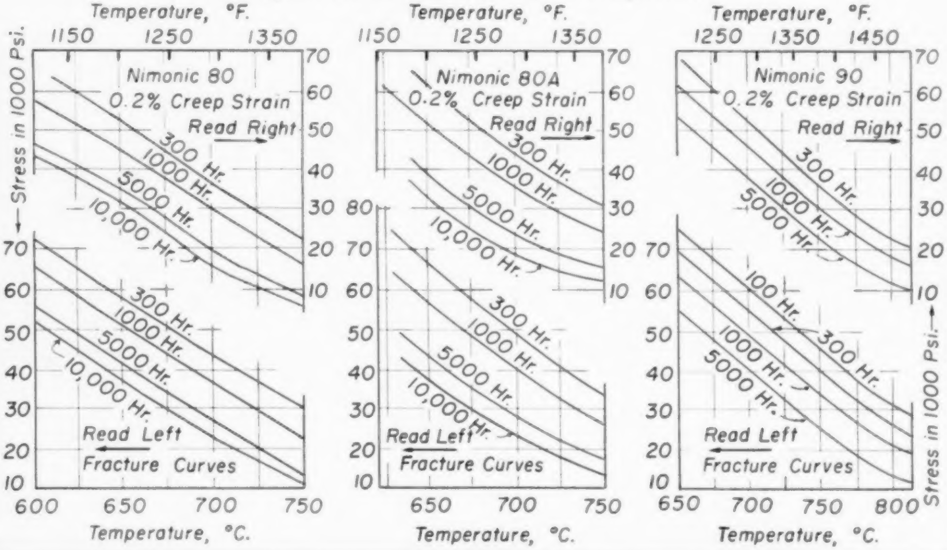
Nimonic 80, 80A and 90 are given solution treatment of 8 hr. at 1975° F., air cooled. Aging is 16 hr. at 1290° F., air cooled.

If Nimonic 80, 80A and 90 are to be cold worked, they should be first annealed at 1825° F. and water quenched. After cold working they should be given the above-mentioned solution and aging treatments.

Air is recommended for atmosphere. Allow 0.003 in. for scale.

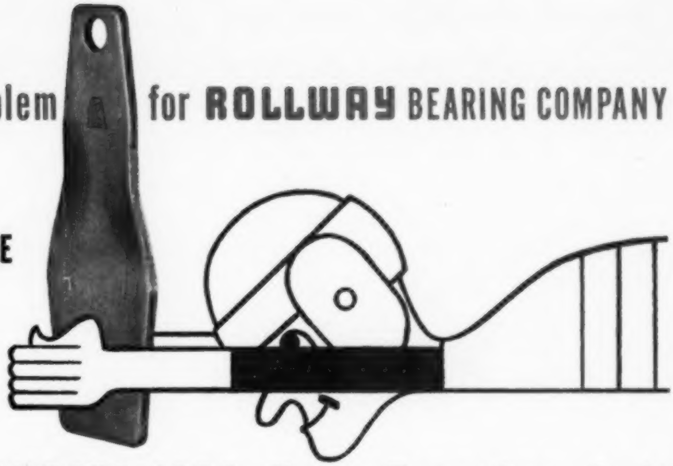
†These are wrought alloys with no guaranteed minimum creep properties.
‡Casting alloys.
(a) Nominal value; nickel is "remainder" except in Nimonic D.
(b) C.g.s. units.
(c) Mean coefficients in millionths per °C.
(d) Microhms per cm. per sq.cm. at 20° C.

Creep and Fracture Stresses at Various Temperatures



We tackled this problem for ROLLWAY BEARING COMPANY

...they saved
20% IN HEATING TIME
35% ON REJECTS



thanks to AEROHEAT® 1200 Heat Treating Salt

Distortion of clutch levers and roller bearing thrust plates treated in a conveyor type furnace was causing a high rejection rate at Rollway Bearing Company. Rollway engineers felt the process could be improved and called in a Cyanamid Technical Representative who recommended a change to AEROHEAT 1200 salt baths.

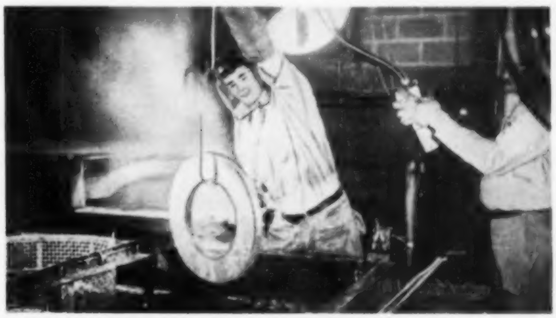
Ends of these clutch levers, hardness 40-46 Rockwell C, are held parallel to within .001".

The clutch lever, SAE 1050-1066, was treated at 1550°F. in AEROHEAT 1200, oil quenched, then tempered at 625°F. for two hours. To meet specifications, the ends of the plate had to be parallel within .001" in the plane of the face. The recommended treatment reduced distortion and cut the reject rate from 40% to 5%.

The roller bearing thrust plate, SAE 52100 or its modification, was heat treated at 1525-1550°F. in AEROHEAT 1200, oil quenched, then tempered at 385-400°F. for 20-25 hours. With a maximum distortion of .010" permissible, average distortion has been .005-.006" since using AEROHEAT 1200. Uniform heating was secured, and heating time cut by 20%.

Here is another example of how Cyanamid technical service and heat treating compounds help you meet high specifications for civilian and defense contracts, so...

Next time call Cyanamid first...



These roller bearing thrust plates, hardness 60 Rockwell C, since treating with AEROHEAT 1200, have an average distortion of only .005-.006".

Cyanamid's heat treating compounds include:

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AEROCASE® Case Hardening Compounds
AEROHEAT® Heat Treating Compounds

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☐ Please send me technical data sheet on AEROHEAT 1200
☐ Please have technical service representative call

*Name*________________ *Position*__________
*Company*__________________________
*Address*__________________________
*City*________________ *State*__________

Printed in U.S.A.

Correspondence

(Continued from p. 80)

reaching saturation, as in the tropics, the steel surfaces remain bright, even when the wrap itself has become moist. For this purpose it has the additional advantage of freedom from any dermatitic effect in contrast to chromates. A further development is the incorporation of sodium benzoate into rubber latex for the purpose of producing, by simple dipping of the article in the latex, a tough and resilient film under which the metal remains bright throughout adverse conditions of exposure. The film can be quickly stripped when no longer required.

"Vapor phase inhibitors" are also being developed for use in the packaging of metal parts; as their name implies, these substances (salts of organic bases) have sufficient vapor pressure to permit the protection of the metal surface (usually steel) at a sensible distance from the source which again may conveniently take the form of an impregnated wrap.

Sodium nitrite, an efficient inhibitor toward steel and cast iron, has a specific attack upon soldered joints. Sodium benzoate is highly inhibited to solder but is not effective toward cast iron; in suitable concentration it has the property of suppressing the attack of nitrite upon solder. The "mixed inhibitor" has proved useful for protecting cast iron, solder and steel when present conjointly, as in the cooling systems of motor vehicles carrying glycol antifreeze. It has also been successfully applied to the treatment of rubber latex.

W. H. J. Vernon
Senior Principal Scientific Officer
National Chemical Research Laboratory
of Great Britain

Jigs for Positioning Keyhole Notch

Weirton, W. Va.

Uniform preparation of keyhole notch impact specimens has resulted from using the two jigs illustrated.

The two blocks are prepared from 1-in. square bar stock by machining a channel 0.394 x 0.394 in. and finishing to a 55-mm. length. A stop plate is screwed to one end of each. A ⅜-in. diameter hole is drilled through one jig approximately 0.04 in. off width center and is fitted with a hardened piece of drill rod which previously had been drilled with a No. 47 drill

(0.0785-in. diameter). The other jig is notched as shown by sawing to a depth of not more than 0.140 in. and then hardened.

The machined impact specimen is placed in the first jig and drilled with a No. 48 drill (0.0760-in. diameter) using slow feed and frequent withdrawal of drill to facilitate removal of the steel cuttings. Reaming of the hole is accomplished by using a No. 47 drill (0.0785-in. diameter) running at moderately fast speed. The drilled specimen is then placed in the other jig and sawed by means of a band saw or hack saw through the shallower dimension to complete the keyhole.

C. D. Foulke
Research Metallurgist
Weirton Steel Co.

Perchloric Acid Explosions

New Haven, Conn.

The letter of P. A. Jacquet on "Electrolytic Polishing of Nickel" in the August 1951 issue of *Metal Progress* (page 65) was noted with interest.

While it is true that perchloric acid and acetic anhydride baths can be used very satisfactorily for electrolytic polishing, I want to call your attention to the fact that mention of this plating bath should not be made unless attention is called to the hazards attendant with its use. Perhaps the tremendous explosion at the O'Connor Electroplating Co., Los Angeles, may be forgotten by your readers, or the full details may not be familiar to them. Also, new readers may not know about the explosion.

Perchloric acid solutions are extremely hazardous to use, and there is danger of spontaneous decomposition with great violence if the

perchloric acid is caused to "explode". This explosion can be caused by overheating or by the presence of a reducing agent, or both. Even small solutions of perchloric acid and acetic anhydride can do heavy damage and may kill the operator if they explode. No one knows what caused the tank to explode at O'Connor Electroplating but the damage was great and many people lost their lives. There are, no doubt, other satisfactory electropolishing solutions that do not involve the hazards met in the use of any compound containing perchloric acid, and perhaps Dr. Jacquet could suggest some other safer type of solution.

WALTER R. MEYER
President
Enthone, Inc.

Editor's Comments

Metal Progress has published three items during the past several years regarding the care that should be taken when using perchloric acid. Gist of these warnings is to chill the ingredients (perchloric acid and acetic anhydride) before mixing because a large amount of heat is evolved; not to electropolish specimens mounted in bakelite or lucite; not to electropolish bismuth or its alloys with hot perchloric acid; to use down-draft fume hoods and ducts of welded steel vented directly to the outside, with the walls and exhaust ducts continually water-sprayed to prevent accumulation of the highly explosive condensate. Baffle plates should not be used unless they can be easily removed and washed. Perchloric acid fumes should never be allowed to come in contact with wood as there is no way of making it safe after it has soaked up perchloric acid.

Spheroidal Cast Irons

PARIS, FRANCE

Certainly the most sensational development in the field of cast iron is the so-called nodular cast iron. Since the graphite occurs in spheroids, the product more properly should be called "spheroidal" cast iron. Graphite exists as random masses with irregular and torn contours in malleable iron, whereas in spheroidal iron the graphite is in crystalline masses radially oriented around a common center, and exists as smooth spherical particles.

Even if we did not know how to make such a metallurgical product (I acknowledge that we do) we could anticipate that such a microstructure would considerably improve the properties of normal irons. Indeed, Sauveur in his "Metallography and Heat Treatment of Iron and Steel" (p. 383) wrote in 1935: "Were it possible to cause the graphite in cast iron to occur in small rounded particles instead of sharp, curved plates, its ductility and strength would undoubtedly be greatly increased."

Spheroidal graphite is obtained by adding small amounts of such elements as the alkali metals or the alkaline earths — specifically, cerium (British Cast Iron Research Assoc.), magnesium (International Nickel Co.), and calcium-silicon (Thyssen). The mechanism of spheroid formation and the determinative factors involved are not exactly known. As in the devitrification of glasses, enamels, and cast basalts (all of which can form spheroidal crystals) the development of spheroids depends upon the phenomena of undercooling, viscosity of the matrix, the relative values of rates of nucleation and crystal growth. As relates to cast iron, several factors are of importance: *(a)* those elements such as sulphur that tend to give white iron, *(b)* the state of undercooling with respect to graphite, *(c)* the nucleation temperature which affects the viscosity of the matrix. Furthermore, nucleation rate can be changed at will by introducing artificial nucleants, whose effect depends upon their melting point, and their crystalline similarity to the solid particles forming from these centers of crystallization. These inoculants or nucleants may either favor the lamellar or spheroidal form, as the case may be, or in addition can offset other nucleants normally present that form lamellar graphite (such as silica or silicate inclusions).

As Professor de Sy indicated in *Metal Progress* (June 1950, p. 774), the existence of these artificial nucleants has been confirmed independently of the optical and polishing effects that first brought them to notice. Professor Thyssen, using the spectrographic method, found magnesium in these germs, which led to the suggestion that the compound Mg_2Si would act as an inoculant — since in magnesium-treated cast iron a silicon addition must follow the magnesium.

Further experiments on the process of the growth of these spheroids would appear worth pursuing, especially experiments involving a quench during solidification, the so-called Boyle's method as used by Laplanche with ordinary cast irons, and by de Sy and Piwowarski with spheroidal cast irons, and by various American workers.

ALBERT M. PORTEVIN

High Purity Zirconium Metal*

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An investigation was conducted by the Research and Development Department of the Foote Mineral Co. for the United States Air Force whose primary object was to prepare zirconium low in hafnium for use in determining the physical properties of essentially pure metal.

Commercial zirconium always contains hafnium, and most of the published properties of the metal are actually the properties of a 3% hafnium-zirconium alloy. Zirconium is relatively abundant, comprising 0.025% of the earth's crust. It is light in weight and resistant to most acid and alkaline solutions.

Zirconium and hafnium (the metal immediately below it in the periodic sequence) are so similar in their chemical behavior that the separation of the two is exceedingly difficult. Zirconium oxide, essentially free from hafnium, was produced by the fractional distillation of a mixture of commercial zirconium tetrachloride and phosphorus oxychloride. The final condensate, corresponding to the complex $1.5\ ZrCl_4 \cdot 1.0\ POCl_3$, was dissolved in methyl alcohol and treated with ammonia, precipitating zirconium oxide.

The purified oxide, consisting of fourteen lots weighing from 4 to 12 lb., was chlorinated directly with one third the weight of 20-mesh charcoal in the chlorinator shown in Fig. 1. Range of composition of the oxide is shown in the second column of Table I. The temperature of the chlorinator was maintained at 1740° F. (950° C.). A flow of 0.1 cu.ft. per min. of chlorine was maintained during the process. Temperature to the main condenser was controlled at 390° F. (200° C.) by strip heaters. No attempt was made to control the temperature of the second and third condensers, but the product of each was held separately in steel containers pending analyses.

This operation yielded 114 lb. of zirconium tetrachloride, which was 52% conversion of the purified oxide. A typical analysis is given in the third column of Table I. The zirconium tetrachloride was then converted to zirconium sponge in the reducing unit shown in Fig. 2. The unit was designed to operate at atmospheric pressure and to produce about 5 lb. of sponge per charge. The shell of the unit was constructed of Type 309 stainless steel. This contained an iron product pot below and a nickel subliming chamber above; the two sections of the shell were sealed with an asbestos gasket and bolted together. Nickel baffle plates were placed over the product pot to prevent solid particles from being carried down and contaminating the sponge. Temperatures of the two sections were controlled separately.

The charge consisted of about 12 lb. of zirconium tetrachloride placed in the subliming chamber, and 5 lb. of sodium placed in the product pot. Potassium chloride was added with the sodium metal to promote segregation of the sodium chloride formed during the reduction. After the unit was assembled it was evacuated to approximately 20-in. mercury pressure and back-filled with helium.

Reduction was carried out by heating the sodium metal to approximately 1475° F. (800° C.) and slowly heating the subliming chamber, containing zirconium tetrachloride, to a maximum of 930° F. (500° C.). The tetrachloride slowly sublimed and the vapor passed down through a central tube into the lower or product pot where it reacted with the sodium metal, thus being reduced to zirconium. The reaction was controlled by regulating the pressure.

After the reaction was completed, the crude sponge and salt matrix was chipped from the product pot and leached with 10% hydrochloric acid. The sponge was then washed free of chloride with distilled water. In this manner a total of 23 lb. of sponge was produced for later purification. The yield on this operation, figured on chloride charged, was 51.7%. Yield from the purified oxide was 27.4%, exclusive of unused fine material. Results of the spectrochemical analysis for metallic impurities in the zirconium sponge are shown in the fourth column of Table I.

The sponge was converted to high purity zirconium in deBoer-type iodide decomposition tubes constructed from both glass and metal.

*Material in this paper is from a contribution to the International Congress of Pure and Applied Chemistry, New York City, Sept. 10, 1951, entitled "Preparation and Some Properties of High Purity Zirconium Metal". The work was done under United States Air Force Contract No. W-33-038 AC 20168.

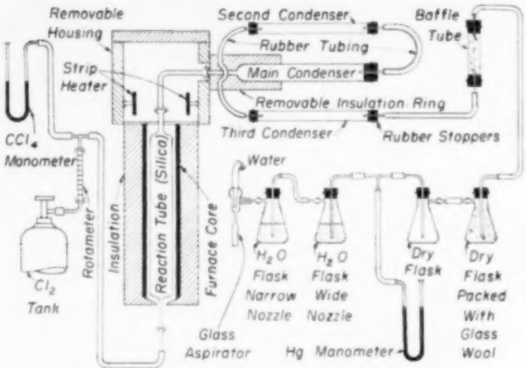


Fig. 1 — Experimental Chlorinator Used to Convert Purified Zirconium Oxide to Chloride

The Pyrex glass tube was 4 in. outside diameter by 28 in. long; ¼-in. tungsten electrodes were sealed in to accommodate a single 0.090-in. zirconium U-filament, 28 in. in length. The 4-in. Inconel tube was 12 in. long, having ½-in. molybdenum electrodes to accommodate a single 0.090-in. zirconium U-filament, 18 in. in length. Molybdenum grids were used to support the crude zirconium during the deposition process.

After loading the tube with wet sponge, it was heated to about 930° F. (500° C.) and evacuated to 10^{-5} mm. Hg pressure. The tube was then cooled to room temperature and 50 g. of iodine added. After sealing, the tube was placed on an iodide decomposition panel and the current adjusted. Tubes were operated at an outside temperature of 390° F. (200° C.). When the purification run was completed, the tubes were opened under argon, flushed with a slurry of methyl alcohol and dry ice, and washed with distilled water.

A total of 7.35 lb. of essentially pure zirconium was produced by the thermal decomposition of the tetraiodide during the experimental work. The yield of zirconium metal was 8.7, 16.5 and 32% based on oxide, tetrachloride and sponge weights respectively, exclusive of unused, off-grade material and fines. A representative spectrochemical analysis of the 29 small lots of metal produced in Inconel tubes is shown in the fifth column of Table I.

Table I — Spectrochemical Analyses of Materials Used for Processing Iodide Zirconium

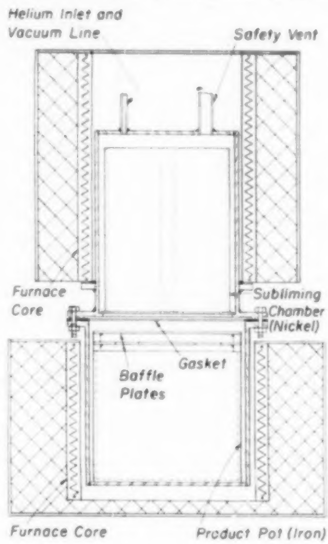
Element	Purified ZrO_2	$ZrCl_4$	Sponge	Iodide Zirconium
ZrO_2*	92 to 97			
Zr			99.52†	99.93†
P_2O_5	1.35 to 4.56			
Al	0.02 to 0.07	0.014	0.037	<0.003
Ca	0.005 to 0.044	0.006	0.007	<0.003
Cu	0.003 to 0.014		0.004	
Fe	0.005 to 0.035	0.019	0.115	<0.003
Mg	0.004 to 0.012	0.012	0.185	<0.003
Ni	0.008 to 0.027	0.011	0.008	0.008
Si	0.004 to 0.173	0.025	0.072	0.017
Ti	0.003 to 0.007	0.004	0.004	<0.003
Hf	0.007 to 0.042	0.028	0.028	0.029

*Determined by wet analyses. †By difference.

Oxygen and nitrogen in the particular lot recorded in Table I (Lot No. 710) were 0.030 and 0.018% respectively. Analyses of the various lots ranged between a minimum of 0.019 and a maximum of 0.086% O_2, and a minimum of 0.002 and a maximum of 0.082% N_2.

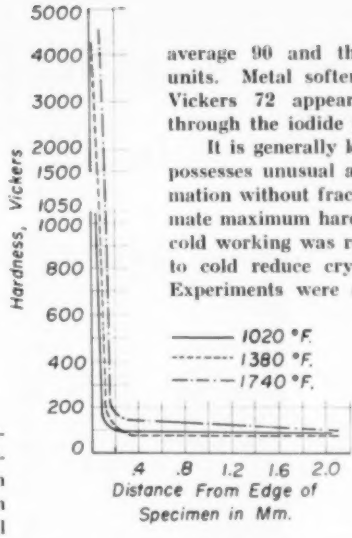
Oxygen was determined by the HCl method. The precision was observed to be ±0.002% in the range of 0.02% O_2. Most of the oxygen was contained near the surface of the metal. For example, a sample of zirconium rod which showed 0.04% O_2 was reduced to 0.02% by removing the surface film prior to analysis. Nitrogen was determined by a modified Kjeldahl method, which is generally accepted for determination of nitrogen in zirconium and titanium.

Fig. 2 — Reducing Unit for Converting Zirconium Tetrachloride to Zirconium Sponge



Comparing the average content of each of the major metallic impurities with the average content of that impurity in the sponge, it was noted

Fig. 4 — Increase in Surface Hardness After Heating Zirconium Metal in Air at 1020, 1380 and 1740° F. (550, 750 and 950° C.) for 2 Hr.



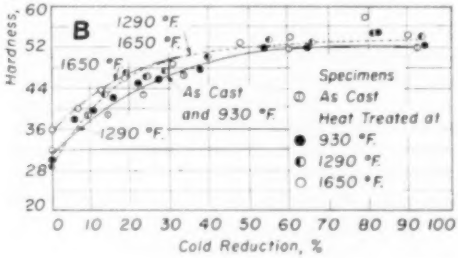
that iodide purification (in 29 runs) reduced the impurity content as follows: Silicon, 31.6% eliminated; aluminum, 62.7%; iron, 87.1%; magnesium, 91.0%; titanium, 48.0%; nickel, none; calcium, 34.2%; and hafnium, none.

PROPERTIES OF IODIDE ZIRCONIUM

Hardness variation of the specimens was attributed to minor differences in oxygen and nitrogen contents, even though this opinion was not substantiated by chemical analyses. These elements could be introduced into the growing rod through *(a)* residual gas not pumped from the tube, *(b)* gas introduced with iodine, and *(c)* minor leaks in tube during deposition.

The average hardness of the 29 samples of iodide zirconium was Rockwell A-20.9 and Vickers 90.1. The maximum value of Rockwell hardness was A-36.3; the minimum A-9.5; the arithmetical average A-20.9 and the standard deviation ±6.7 units. The maximum value of Vickers hardness was 140; the minimum 72, the average 90 and the standard deviation ±17 units. Metal softer than Rockwell A-9.5 and Vickers 72 appears impractical to obtain through the iodide purification process.

Fig. 3 — (A) Cold Reduction Versus Hardness for Crystal Iodide Bar and (B) Arc Melted Ingot



It is generally known that iodide zirconium possesses unusual ability to absorb cold deformation without fracture, even after the approximate maximum hardness value attained through cold working was reached. It is quite common to cold reduce crystal bar 95% in thickness. Experiments were conducted to determine the effect of quenching from above and below the transformation on the shape of the hardness versus cold reduction curves.

The material chosen for these experiments has the following analysis: 0.13% Si, 0.072% Al, 0.018% Mg, 0.077% Fe, 0.010% Ti, 0.010% Ca, 0.002% N, 1.90% Hf, and 97.78% Zr (by difference).

Specimens of crystal bar and arc melted ingot were wrapped in sheet zirconium and heat treated in welded iron cans back filled with helium. The specimens were quenched after heating for 16 hr. at 930, 1290, and 1650° F. All specimens were cold rolled to approximately 0.025 in. thick. Rockwell A hardness values plotted against per cent cold reduction are shown in Fig. 3A and B.

Quenching from 1650° F. (above the transformation) hardened the crystal iodide bar (A) 10 points on the Rockwell A scale, and the arc melted bar (B) 4 points. Cold working the quenched bars A increased their hardness at a more rapid rate than arc melted bars B, but all bars quenched from 1650° F. reached maximum hardness of about A-54 after 60% and higher reduction (cold).

Initial hardness of bars as-quenched from below the transformation was about 8 Rockwell A points lower than when they were quenched from 1650° F. This differential was reduced to about 3 points after 25% cold reduction. Iodide bars A initially quenched from the lower temperatures were always softer in cold worked condition than if previously quenched from 1650° F.; arc melted bars B had about the same hardness after 60% or more cold reduction irrespective of prior heat treatment.

These observations suggest certain structural changes in zirconium, probably resulting from impurities, which warrant further investigation.

In order to determine the extent of oxygen

penetration in relatively pure zirconium (99.87% Zr, 0.062% Hf, rest Si, Al, Mg, Fe, Ti, Ni, Ca and Cu), duplicate cold swaged $\frac{3}{16}$-in. diameter rods were heated in still air at 1020, 1380, and 1740° F. for 2 hr. The extent of penetration was determined on polished cross sections by measuring Vickers hardness, using 1200-g. load for 20 sec., at various distances from edge of specimens. Results are plotted in Fig. 4.

It was observed that maximum penetration was 0.35 mm. at 1380 and 1740° F., even though the hardened zone at higher hardnesses (above 200 Vickers) penetrated deeper at the latter temperatures. At 1020° F., the penetration was 0.2 mm. The higher hardness of the core on the 1740° F. specimen probably resulted from structural changes due to the transformation.

Fig. 5 *(right)* — Iodide Zirconium Containing 0.001% H_2. Structure relatively free of second phase but containing twins. Etched with modified Tucker's reagent. 500 ×

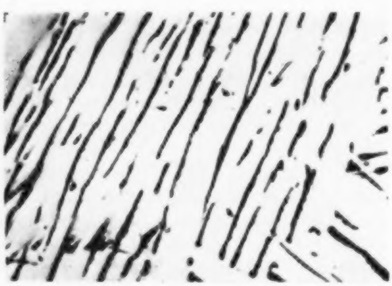


Fig. 6 — Iodide Zirconium Containing 0.010% H_2 With Normal Structure. Etched with modified Tucker's reagent. 500 ×

These data indicated that, when desirable, zirconium could be worked in air below the transformation temperature, 1583° F. (862° C.), without deleterious effect on the properties of the base metal. Penetration of oxygen (and probably nitrogen) was substantially less than 0.5 mm. for 2-hr. heating period.

The oxidized layer during these tests was black, and adhered to the zirconium specimens. Minor impurities or a combination of impurities radically affect the extent and nature of the oxidized layer. Aluminum and nitrogen contents (approximately 0.1 and 0.01% respectively) were particularly harmful. The oxide is not protective. However, surface grinding to remove 0.5 mm. from the surface is generally sufficient to remove the oxidized surface.

The microstructures of two specimens of relatively pure zirconium are shown in Fig. 5 and 6. The essential difference in analyses is in hydrogen content. Zirconium containing 0.001% H_2* is shown in Fig. 5. The metal is substantially single phase, showing some twins. Figure 6 shows a considerable amount of second phase. The hydrogen content of this specimen was 0.010% H_2.* Time did not permit identification of the second phase. Evidence pointed toward two possibilities: *(a)* Metastable beta retained as a result of minor impurities, and *(b)* a stable constituent, such as zirconium hydride or an intermetallic compound.

CONCLUSIONS

1. A total of 7.35 lb. relatively pure zirconium was produced for determination of certain basic physical properties. The material analyzed about 99.9+ zirconium.

2. Comparing the average content of each of the major metallic impurities in iodide refined zirconium with the analysis of crude zirconium starting material, it was noted that iodide refinement reduced Si, Al, Mg, Fe, Ti and Ca substantially, but there was no reduction in nickel and hafnium.

3. The work hardening curves for iodide and arc melted iodide zirconium were similar, except that approximate maximum hardnesses were attained at 70 and 60% cold reduction, respectively. The maximum hardness was Rockwell A-52 for both materials after 90% cold reduction.

4. The penetration of oxygen into zirconium at 1020, 1380, and 1740° F. was determined for 2-hr. heating periods in still air. Hardness measurements showed that approximately 0.35-mm. penetration occurred at 1380 and 1740° F.

5. The hardness of iodide zirconium was Rockwell A-20.9 ± 6.7 (Vickers 90 ± 17). Minimum value was Rockwell A-9.5 (Vickers 72). These are the lowest reported for zirconium, indicating exceptional ductility and purity.

*Hydrogen was determined by vacuum fusion method by Battelle Memorial Institute.

Ceramic Coating Increases Life of Engine Exhausts

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EXHAUST SYSTEMS for aircraft engines consist of ducts of complicated shape which collect the hot combustion gases from the various cylinders and lead them safely away to supercharger units, to heat interchangers, and to exhaust. Gases issuing from internal combustion engines, as everyone knows, are very hot; ducts near the entrance may reach 1800° F. The exhaust systems must be made of thin sheet alloys which will not only resist oxidation in air on the outside, but carburization from the carbon monoxide in the hot gases. Concentrated blast effect ("blow-torch action") is involved at certain spots. The exhaust also carries appreciable quantities of lead bromide ($PbBr_2$) derived from chemicals introduced into the gasoline to increase its octane rating. As there is considerable vibration in the entire engine mount, the possibility of fatigue failure is not to be discounted.

Obviously, very superior metal and construction are needed to insure service without failure for considerable periods in this most critical service. Alloys high in the strategic metals nickel or cobalt or columbium (such as Inconel X, N-155 and Hastelloy C) have been used. Likewise 19-9DL stainless steel has given satisfactory service in engines on commercial aircraft. This alloy has about the minimum of strategic metals and we at Ryan Aeronautical Co. felt that if its life could be extended by the use of ceramic coatings, an important forward step would have been taken not only from a standpoint of better service in aircraft engine exhaust systems but as a substantial aid in the conservation of critical elements which are in short supply and which are generously used in corrosion and heat resistant alloys. Success would mean that the so-called "luxury" class of alloys in many applications could be supplanted by cheaper alloys given the benefit of life-extending ceramic coatings.

Such ceramic coatings had already been formulated and studied by the National Bureau of Standards. Considerable laboratory work, sponsored by the National Advisory Committee for Aeronautics, has indicated their protective power.* A test showed that the coating known as Bureau of Standards No. A-417 is not affected by thermal shock as encountered in exhaust system service at any temperature between −75 and 1700° F. It will also stand a surprising amount of mechanical impact without sustaining damage.

In order to obtain the most useful test data, Ryan Aeronautical Co. manufactured a number of exhaust system components not only of ceramic coated 19-9DL but also of a variety of uncoated alloys, and arranged with Pan-American World Airways for them to be used on the engines of Boeing 377 Stratocruisers in trans-Pacific service. These aircraft were selected because they offered the best combination of advantages desired in the experiments. Their four 3500-hp. Pratt and Whitney engines are the largest piston-type engines, and the trans-Pacific flight developed the maximum test hours per month due to the long distances flown.

The components chosen for these flight tests were the "headers" which channel the hot gases from the cylinders to the collector ring, and are the hottest part of the exhaust system. The test headers were removed from the engines at specified intervals, returned to Ryan for metallurgical examination, and later replaced.

THE CERAMIC COATING

Bureau of Standards describes ceramic coating A-417 as consisting of 70 parts by weight of Frit 331, 30 parts of chromic oxide, 5 parts of enameling clay, and 48 parts of water. Frit 331, in turn, is 38% SiO_2, 6.5% B_2O_3, 44% BaO, 4% CaO, 5% ZnO and 2.5% BeO. The coating is milled to a fineness where only 0.4 g. remains

*N.A.C.A. Technical Note 2380 (June 1951) entitled "Effectiveness of Ceramic Coatings in Reducing Corrosion of Five Heat Resistant Alloys by Lead Bromide Vapors", by Dwight G. Moore and Mary A. Mason of National Bureau of Standards, says that "ceramic coatings are being used successfully for exhaust stacks on patrol bombers and for the heat exchangers on heavy bombers". (See p. 166.)

on a 200-mesh sieve from a 50-cu.cm. sample of slip. Enough water is added to make a slip of 1.8 specific gravity; the parts are cleaned, dipped in the slip, drained, and fired at 1850° F.

Since the ceramic coatings made in this way are extremely thin, from 0.001 to 0.002 in. in thickness, the weight increase is small, amounting to 2% on 0.065-in. gage. In application, it is simpler to apply thin coatings than thick, and the control of thin coatings is more or less automatic when the slip has the correct dilution. Heavier coatings tend to spall after firing.

Parts coated with this ceramic will stand an amazing amount of rough treatment, so that handling does not constitute a problem. For example, if realignment of a coated part is necessary it may be placed in jigs, rubber mallets can be used, alignment jacks and heat may be applied — all without chipping, crazing or other damage to the coating.

Thermal Shock Test — A special test was conducted to ascertain the thermal shock resistance of the A-417 ceramic coating, as applied to the Ryan exhaust system headers:

First Run: Specimens were cooled 18 hr. to −75° F. with dry ice in a refrigerator and then heated rapidly with a gas burner to 1700° F.

Second Run: Cooled to −70° F. for 4 hr. and then heated to 1500° F.

Third Run: Cooled to −70° F. for 19 hr. and then heated to 1600° F.

One hot specimen from each of the above test runs was dropped 6 ft. to a concrete floor; it was dropped again when cold. Handling time was limited to 10 sec. After all tests there were no cracks, chips or other damage to the coating.

Consequently, it may be concluded that this ceramic coating stands up under severe shock induced by extreme temperature changes and is not susceptible to mechanical damage at extreme temperatures.

SERVICE TESTS

For the tests, Ryan production departments fabricated exhaust headers of the following material all in 0.043-in. gage and labeled each by nameplates attached:

19-9DL stainless steel* with ceramic coatings on both interior and exterior.

19-9DL stainless steel with ceramic coatings on interior only.

19-9DL stainless steel, uncoated (three control headers).

17-14 CuMo,* uncoated.

Modified Type 310,* uncoated.

Type 310* stainless steel with columbium, uncoated.

Inconel X,* uncoated.

N-155,* uncoated.

Hastelloy C,* uncoated.

Tests before and after service consisted of metallographic examinations, spectrographic analyses, microhardness readings and dial gage micrometer measurements. All headers were installed on the same cylinder banks of the Pratt and Whitney engines, namely, row B. Test headers were removed from the aircraft at intervals of approximately 650 and 1000 hr., and finally between 1234 and 1623 hr. The wear bands of each header were sawed off, test samples were taken from the header bodies at the hottest areas adjacent to the wear bands, new wear bands were welded on, and the test headers were returned to service.

All 19-9DL test headers were removed after 650 hr. on P.A.A. Stratocruisers, and brought to the Ryan Development Laboratories for examination. Ceramic coated headers were compared with those which were not coated. It was found that the ceramic coatings had prevented oxidation, carbon absorption and corrosion attack, and had consequently protected the headers successfully. For the first time in Ryan experience, an examination of exhaust header sections with 650-hr. service disclosed no signs of deterioration.

Specific details of the examinations follow.

19-9DL — No reduction in gage thickness was found in the header coated on both sides. Some reduction (0.003 in.), due to scaling on the exterior, was found in the header coated on the interior only. The wholly uncoated header was reduced in thickness by 0.008 in.

Figure 1B (see p. 89), taken from metal at the hot zone, interior, of the header coated on both sides, shows a definite white layer immediately under the ceramic material. This metal has been decarburized. Figure 1A, a ceramic coated header not tested, does not exhibit this

*Type analyses are as follows:

19-9DL — 67 Fe, 19 Cr, 9 Ni, 1.3 Mo, 1.2 W, 0.7 Si, 0.6 Mn, 0.3 Cb, 0.3 C, 0.2 Ti.

17-14 CuMo — 60 Fe, 17 Cr, 14 Ni, 3 Cu, 3 Mo, 1.0 Mn, 0.5 Si, 0.5 Cb, 0.3 Ti, 0.10 C.

Modified Type 310 — 52 Fe, 25 Cr, 20 Ni, 1.3 Mn, 0.5 Si, 0.06 C.

Type 310 Cb — Above with 1.0 Cb.

Inconel X — >70 Ni, 15 Cr, 7 Fe, 2.5 Ti, 1.0 Cb, 0.7 Al, 0.65 Mn, <0.50 Si, 0.2 Cu, 0.08 C.

N-155 — 27 Fe, 21 Cr, 21 Co, 21 Ni, 3.2 Mo, 2.5 W, 1.5 Mn, 1.2 Cb, 0.7 Si, 0.14 N, 0.10 C.

Hastelloy C — 58.5 Ni, 16.5 Mo, 14.5 Cr, 5.5 Fe, 4.5 W, 0.3 V, 0.15 C.

Fig. 1A — Metal Beneath Ceramic Coating Before Test

Fig. 1B — Interior of Header; White Layer Under Ceramic After 650 Hr.

Fig. 1C — Exterior of Uncoated Header After 1269 Hr.

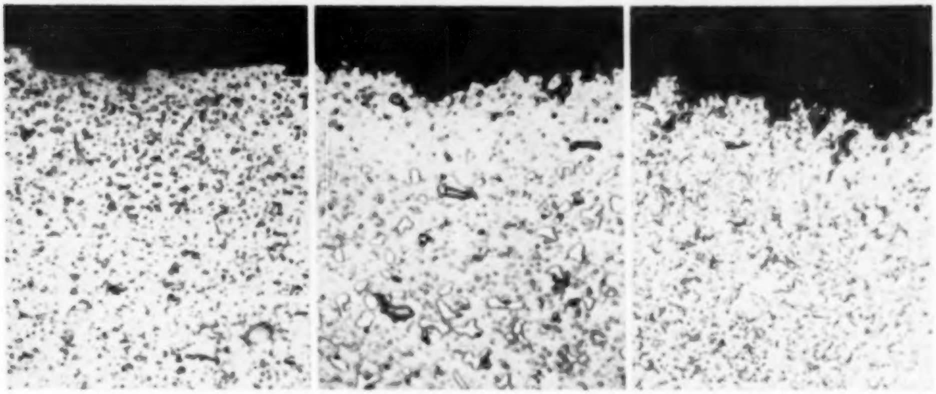


Fig. 1A, B and C — 19-9DL in Exhaust Headers, Before and After Test, Protected and Bare. Etched with glyceregia; magnified 200×

characteristic. Therefore, decarburization is the result of conditions experienced in operation. Figure 1B also shows that sigma constituent (particles with a light tone) has formed in the chromium-nickel solid solution during its long stay at high temperature.

The ceramic coatings have protected the surfaces. The interior of this header was very smooth. The original green color of the ceramic coating had changed to black. Spectrographic analysis indicated that this black coating contained the same ingredients as the original green coating — showing that the ceramic material had not been removed but merely changed in appearance.

Examination of the exterior of the 19-9DL header, which was coated only on the interior, revealed that thin "roots" of oxide have penetrated the metal about 0.002 in. Otherwise, there was no observable change from Fig. 1A.

Microhardness tests of a sample similar to Fig. 1B gave readings of Rockwell C-20.5 at about 0.0005 in. below the surface, and an average interior hardness of C-25.0. The header coated on both sides averaged C-19.1 hard at the surface and C-23.5 in its interior.

Observation and experience in the Ryan Development Laboratories have shown that much of the deterioration of unprotected headers has been due to carbon absorption, with resultant surface embrittlement. In all previous examinations of exhaust headers after 650 hr. of service, there has been a definite increase in carbon content at the surface, and much oxide penetration into the microstructure. Ceramic enameling prevents this carbon absorption, eliminates oxidation and inhibits corrosion, thus extending the life of such components.

Figure 1C, taken of an uncoated 19-9DL header after 1269 hr., shows a typical salt-and-pepper structure of carbide and sigma which is characteristic of the alloy after 400 hr. of service life. There is some oxide penetration at the surface, and a moderate build-up on the surface. Aside from the tendency to absorb carbon, the time factor makes very little change in the general structure of this material.

Spectrographic analyses of the test headers which were coated with ceramics showed that the ceramic coatings were still present after 1234 hr., protecting the surfaces from oxidation. The exterior surface of the header coated only on the interior with ceramic had some oxide present, although excessive deterioration had not yet been encountered.

Type 310 With Columbium — The test header fabricated from Type 310 stainless steel with columbium added seemed to be in better condition than the other uncoated headers after 1368 hr. of test because there was little evidence of oxidation. Figure 2 shows a slight tendency toward decarburization in this uncoated header. There has been no grain boundary precipitation. However, there are large islands of sigma interspersed with small particles of carbide. The sigma formation is not continuous and will probably leave the material in a relatively ductile condition, similar to 19-9DL. It is interesting to note that the sigma particles in 19-9DL are smaller; compare Fig. 1C and Fig. 2.

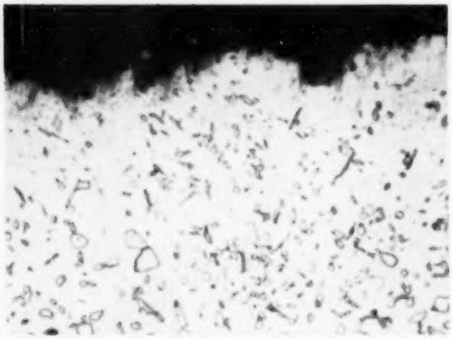
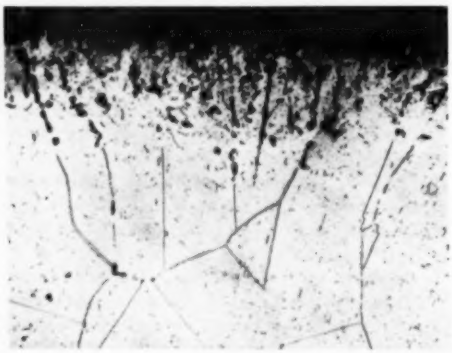


Fig. 2 — Type 310 Cb, Uncoated, After 1368 Hr. Carbide and sigma particles; slight decarburization; no oxide. Etched with glyceregia; 200×

Modified Type 310 — The hottest area, interior of such a header after 1098 hr. in test, has very large grains outlined with continuous carbides. There is also some spheroidal sigma at the grain boundaries. Within the grains, both spheroidal and needle sigma have formed. Oxide has begun to penetrate at the grain boundaries at the surface.

Fig. 3 — Modified Type 310 Stainless, Uncoated, After 1623 Hr. in Test. Deep oxide penetration on surface. Grains contain sigma particles. 100×



Later examination of the header, after 1623 hr. in test, indicates a progressively deeper grain boundary penetration due to oxidation and corrosion. Figure 3 exhibits this trend. There is also a heavier development of sigma along the grain boundaries (together with the carbides). Other areas show even more severe cases and greater depths of penetration along grain boundaries. In all probability, such material would exhibit brittleness in a bend test.

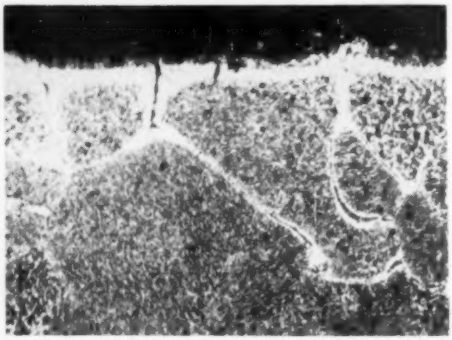
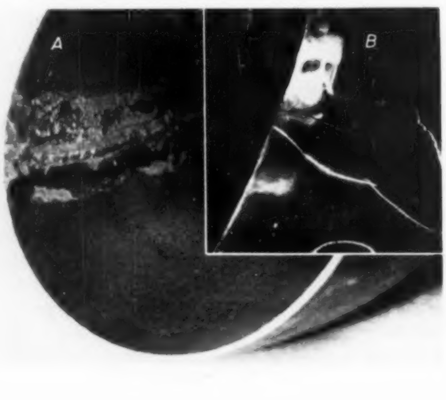


Fig. 4 — Overaged Inconel X After 1385 Hr. Material at face and nearby grain boundaries is altered by gain or loss of some normal constituent. 100×

Inconel X — Figure 4 was taken of the Inconel X header after 1385 hr. in test. Some intergranular penetration was probably caused by corrosion at the altered grain boundaries, where some constituents are either added or lost. The inner structure is in a severely overaged condition. The exterior presents a smooth appearance with very little oxidation.

Hastelloy C — Microstructure of the Hastelloy C header after 1234 hr. in test shows a condition of extreme overage together with coarse granular precipitate along the grain boundaries. This has made the material extremely brittle. On a bend test, it fractured without taking a permanent set, which demonstrates complete absence of ductility. This brittleness made it necessary to stop further service testing, even though a new wear band could have successfully been welded to the part. Upon parting the

Fig. 5 — (A) Erosion Inside Header Caused by Gases After 1234-Hr. Service. (B) Spontaneous crack started from dormant oxidized notch



Original Structure . Oxide Penetration Carbide Precipitation

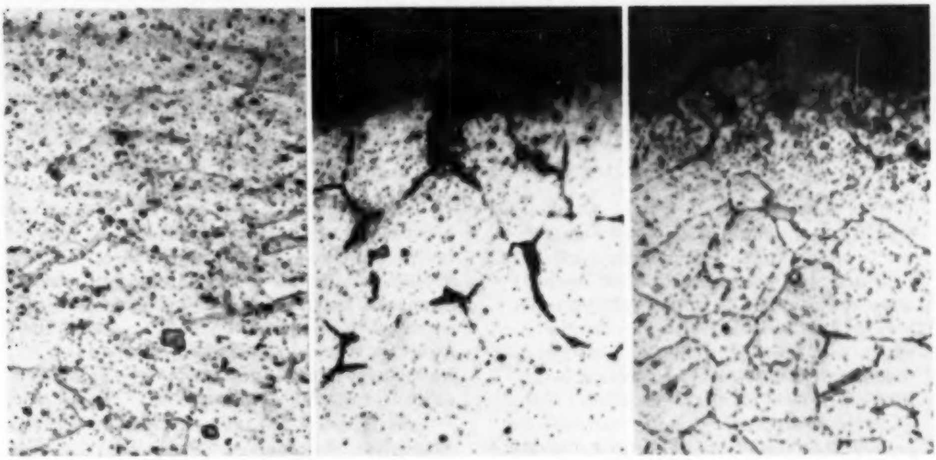


Fig. 6A, B, and C — Microstructure of Test Header Made of 17-14 CuMo Which Was Deeply Corroded at Hottest Spot After 472 Hr. in Test. Glyceregia etch; magnified 200×

wear band from the header to obtain a metallographic specimen, the part cracked spontaneously, as shown in Fig. 5B. This crack started from a defect which had existed under the wear band but was in a dormant state and completely filled with oxide. In addition, erosion had set in adjacent to the weld seam in the hottest part of the header, as shown in Fig. 5A.

17-14 CuMo — The test header fabricated from 17-14 CuMo alloy was removed from service after 472 hr. because of excessive thinning, due to intergranular corrosion at the surface of the material and to high-temperature oxidation.

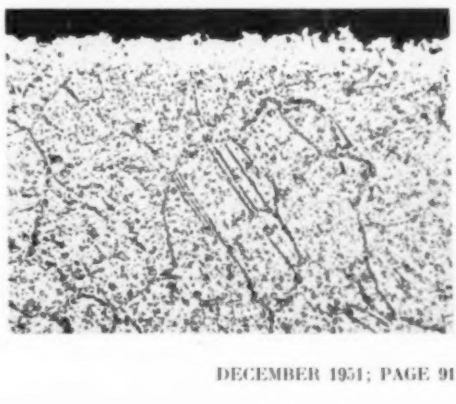
The wear band had a thickness of 0.064 in. where least affected, and measured from 0.032 in. down to a knife edge at the area most affected. The body of the stamping had a thickness of 0.036 in. at the coolest operating portion and a thickness of 0.030 in. where impingement of hot exhaust gases appeared to be greatest. At the edge of the top of the weld seam, a measurement of 0.032 in. was obtained and $\frac{1}{32}$ of an inch away from the weld, 0.027 in. was the thickness.

Figures 6A, B and C are selected from a microstructural study of this part. Figure 6A is the original structure, free from grain boundary precipitates. Figure 6B shows an advanced condition of intergranular corrosion in the hottest operating area of the wear band. Figure 6C, taken at the hottest operating area where the exhaust gas impinged, shows heavy carbide precipitation, carbon absorption with oxide penetration, and intergranular attack along grain boundaries at the surface.

It was apparent that the test header fabricated of 17-14 CuMo does not have the ability to withstand the high temperatures at which this part operates; oxidation and carbide precipitation lead to rapid deterioration. It is seldom that intergranular corrosion is observed in parts designed for conducting gases at elevated temperatures. Most usable materials, even though containing high percentages of unstabilized carbon, develop a tightly adherent film

(Continued on p. 166)

Fig. 7 — Inside Surface of N-155 After 1098 Hr. in Test. Note white surface layer, precipitation at grain boundaries, and particles of secondary phase (or phases) within the grains



Shock Wave Propagation in Metals

Shock loads in the draft gear of a long freight train may possibly represent the worst impact in peacetime equipment, but they are mild compared to what happens when armor is hit by a high velocity shell, a shaped charge, or resists the detonation of an explosive plastered on. Werner Goldsmith, in a well-received lecture before the Golden Gate Chapter, outlines some of the methods used by mathematicians to predict the location and size of the maximum stresses within the metal — methods that yield results broadly verified experimentally by ultra high-speed photography. As a byproduct of these researches, a more useful type of impact test than the Charpy or Izod may confidently be expected.

By Werner Goldsmith
Assistant Professor of Engineering Design
University of California
Berkeley, Calif.

The subject of shock propagation in engineering materials, with particular emphasis on metals, is intimately connected with the design of structures and machine components. As such, it is of considerable interest to the engineer who must perform the design calculations, as well as to the metallurgist who supplies the empirical data that are required to evaluate the strength and resistance of these materials.

Prior to the last decade, almost all stress analysis and property determination was based on the condition of static loading, that is, the gradual application and indefinite sustaining of external forces. Two other methods of load application were recognized — namely, reversed or alternating loads, such as occur in a rotating shaft centrally loaded, and rapid or impact loads. However, the difficulties involved in the analysis of these were so formidable that they have only recently been resolved in part.

Shock loading represents the exact opposite of static loading and consists of the instantaneous application of an external force to a structural member. In practice neither extreme is ever achieved, and thus one deals in all cases with more or less rapid loading which in the limit approaches the respective characteristic behaviors cited previously. Luckily, most instances of slow load application deviate negligibly from ideal static loading, while fairly rapidly occurring phenomena exhibit many features analogous to those of shock loading. It is difficult to assign a specific dividing line between the two regimes; an arbitrary boundary is frequently postulated in terms of initially applied strain rate such that the first marked deviations occur in the expected stress-strain curve of the material when this value is first exceeded. A representative quantitative figure for such strain rates for metals might run from about 50 to 200 in. per in. per sec.

Examples of impact loading would include automobile collisions or airplane crashes and the following engineering applications: Drop forging, lathe and milling operations, braking action for any moving system, blast loading, a projectile striking a target, and contact explosions. The latter is a good example of one of the most rapidly applied types of loading and will be discussed later in more detail.

TWO FUNDAMENTAL DOMAINS

The proper analysis of impact loading requires an understanding of two separate yet interrelated domains: The material's properties under dynamic loading, and the transmission phenomena associated with such collisions. We have made some progress toward a solution of the problem in both areas, but a long and arduous road still lies ahead before a complete evaluation of them can be achieved.

The stress-strain curve for any material is equivalent to the "equation of state" required in analogous problems in hydrodynamics and aerodynamics. Variation of the rapidity of load application may be recognized by an additional parameter — the strain rate. The use of this term is quite limited, since it has been shown that the final strain distribution, and consequently the strain rate, in specimens subjected to tensile or compressive impact tests is quite nonuniform, due to propagation effects of the shock; this makes the analysis quite difficult. Despite this and other limitations, use of the strain rate param-

eter will be made in this exposition as a matter of convenience.

The normal static tensile stress-strain curve for a representative material, such as mild steel, is shown by the bottom graph in Fig. 1. Points A and B represent, respectively, the upper and lower yield points, while BC is the region of strain hardening and D denotes the ultimate strength of the material. Top graph in Fig. 1 qualitatively represents the effects of strain rate on the stress-strain curve, showing an apparent increase in the resistance of the medium with increased rate of load application. This phenomenon is generally known as the "speed effect". It should be emphasized that the various materials react differently to this speed effect, some indicating negligible or no variation with speed, and others exhibiting even slight reductions (rather than larger increases) in the yield stresses and ultimate strengths. It should be further stated that the analyses of the various impact tests frequently neglect phenomena associated with the transmission of stress within the test piece, casting considerable doubt on the validity of dynamic stress-strain curves, so that many investigators have preferred to rely on the static stress-strain curve for the examination of impact processes until the dynamic properties of various engineering materials have been more firmly established.

USE OF IMPACT TESTS

In this connection, it might be stated that cognizance of the variation of material behavior led to early attempts to evalate this effect under impact conditions. The Izod and Charpy notched-bar impact tests have been used to provide a criterion for the applicability of various materials subjected to impact loading. However, while some valuable information resulted from the use of these tests, they do not provide the dynamic stress-strain curve required for the analysis of impact phenomena, and the "energy to fracture" or "impact value" obtained by these techniques only provides a relative scale for the various materials rather than an absolute criterion of dynamic behavior.* Furthermore, the stress concentration present, due to existence of the notch, completely obscures the variation of the metal in its resistance to dynamic effects.

*Editor's Footnote: Doubts as to the utility of conventional impact tests have long been held by practicing metallurgists. See, for example, the article, "How Accurate Is the Impact Test?", by the Metallurgical and Research Committee of the Forging Manufacturers Assoc., p. 69 of this issue.

Transmission phenomena are generally analyzed by standard equations involving the conservation of mass, momentum and energy. It is generally assumed that metals are incompressible so that their density remains constant.

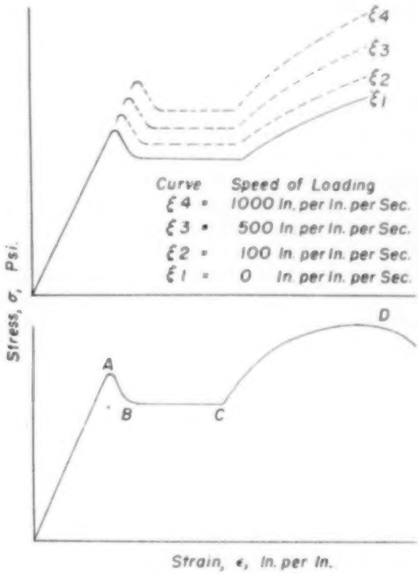


Fig. 1 Tensile Stress-Strain Curves for Mild Steel Under Static Loading (Bottom) and Dynamic Loading (Top) When Strength Increases With Increase in the Rate of Load Application

The process of impact produces in the two colliding members a wave or a series of waves which propagate from the point of contact both along the surface and toward the interior of the two bodies with certain characteristic velocities, depending upon the pressure amplitude. These leave behind a state of strain and a residual particle velocity that is dependent upon the stress-strain curve of the material. With blast or explosive loading, and in certain types of impact loading, this wave propagation need only be considered for the structure or machine component of interest.

Reflections of these waves occur both at free and fixed surfaces of the material, at changes of cross section, and at changes in the material itself. These superimpose themselves upon the incident wave, and the resulting complex stress system will then act on the metal. These effects, as well as those associated with the rapid drop in intensity of load which usually occurs, introduce considerable compli-

cations in the analysis. The magnitude of reflected and transmitted waves is computed from the boundary conditions *(a)* in which no stress can be experienced at a free end and *(b)* a fixed end wherein no particle velocity can exist. Intermediate instances of change of cross-sectional area are treated similarly.

TYPES OF WAVES PRODUCED BY IMPACT

The possible types of waves resulting from impact loading are waves of compression, rarefaction (tensile waves), shear, bending, and two types of surface waves. The latter two categories introduce unwarranted complexities and will be excluded from the present discussion (as will torsional waves which undoubtedly must exist, but have yet not been fully described). Compressive waves are generated in a medium when, for example, it is struck by an explosive blast, while tensile waves are generated when a wire fixed at one end is suddenly pulled by means of a falling weight. Shear waves are always produced when a tensile or compressive wave strikes a bounding surface obliquely or passes through a point of change of material or through a change of cross-sectional area.

Compressive, tensile and shear waves are represented in Fig. 2, with an appropriate external impact load F producing a wave (which is represented exponentially in a bar with a fixed end. The compressive wave travels with velocity c corresponding to a maximum stress σ_{max}, and induces behind it a particle velocity u in the same direction as the direction of wave propagation. Whenever the stress-strain curves in tension and compression may be assumed as identical, a wave of equal stress amplitude will propagate with the same velocity in tension as in compression, but the particle velocity induced behind the wave front is opposite to the direction of wave propagation. A shear wave will travel continuously from one edge of the bar to the other, leaving behind a particle velocity which also changes direction continuously along the bar, but is always perpendicular to the mean direction of wave propagation.

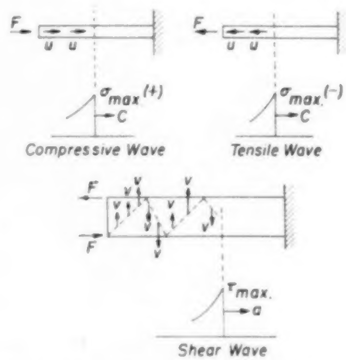


Fig. 2 — Experimental Representation of Compressive, Tensile and Shear Waves

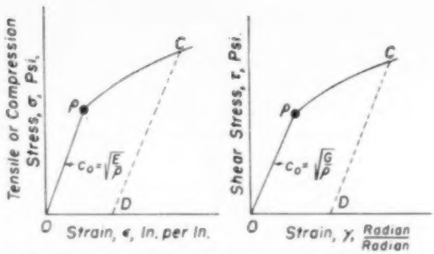


Fig. 3 — Idealized Stress-Strain Curves for Use in Computing Velocity of Wave Propagation of Tensile, Compressive and Shear Impacts

The velocity of wave propagation c in tension and compression, and a in shear, and the induced particle velocities u and v may be computed to a good first approximation from the respective stress-strain curves for tension, compression and shear for an idealized material approximating that of many actual metals. This is shown in Fig. 3. (A yield point cannot be incorporated as this would involve a negative value for the velocity of wave propagation, which is physically impossible. In an actual material this difficulty is obviated by a discontinuous jump between two points of the stress-strain curve.) These velocities are given by the following relations:

$$c = \sqrt{\frac{1}{\rho} \cdot \frac{d\sigma}{d\varepsilon}}$$

(propagation velocity)

$$u = \int_0^{\varepsilon} c\, d\varepsilon = \frac{1}{\rho}\int_0^{\sigma} \frac{d\sigma}{c}$$

(particle velocity)

for tension and compression, while for shear waves

$$a = \sqrt{\frac{1}{\rho} \cdot \frac{d\tau}{d\gamma}}$$

(propagation velocity)

$$v = \int_0^{\gamma} a\, d\gamma = \frac{1}{\rho}\int_0^{\tau} \frac{d\tau}{a}$$

(particle velocity).

If the materials exhibit proportional limits, as indicated in Fig. 3, the propagation velocities within the elastic region are constant, so that the first and third of these equations become

$$c = \sqrt{\frac{E}{\rho}}$$

$$a = \sqrt{\frac{G}{\rho}}$$

where E represents the modulus of elasticity in

tension and compression, and G the modulus of elasticity in shear. The permanent strain existing at any point of the bar may be obtained from the stress-strain curve at the appropriate local maximum stress.

Since any impact load is applied only for a finite duration, removal of the load will initiate the propagation of an unloading wave which will travel along the bar in a manner similar to a tension or rarefaction wave. It has been found that whereas the loading occurs along the stress-strain curve to the required maximum stress (along line OC of Fig. 3), the unloading wave will travel along the line CD, which is parallel to the maximum slope of the stress-strain curve (or, as in the present situation, parallel to the elastic region). Thus, the unloading wave travels with velocity c_o (the velocity of elastic waves) which, from the first equation and the assumed stress-strain curve, may be recognized as the fastest propagation velocity possible in a metal. Therefore, correspondingly higher stresses will propagate at slower velocities in a material having a continuous concave downward stress-strain curve beyond the elastic limit.

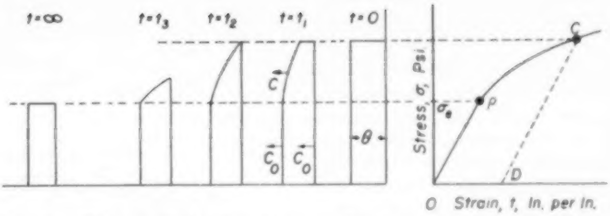


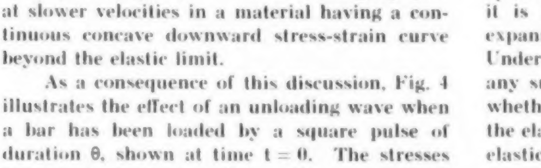
Fig. 4 — Effect of Unloading Wave on Bar Loaded by Square Pulse

As a consequence of this discussion, Fig. 4 illustrates the effect of an unloading wave when a bar has been loaded by a square pulse of duration θ, shown at time $t = 0$. The stresses in the elastic region, below the proportional limit P at stress σ_e propagate at the elastic constant velocity c_o, as in the case for the unloading wave, while the stresses in the plastic region lag behind. At time $t = t_2$, the unloading wave has effectively caught up with the maximum stress; beyond this point it proceeds to cut off the upper portion of the pulse, so that positions beyond that corresponding to time $t = t_2$ never experience the maximum stress to which the bar was subjected. Furthermore, at time $t = t_2$ the catching up of the release wave with the peak stress wave results in a generation of a secondary wave which further complicates the stress pattern. At infinite time the wave in the bar would be reduced entirely to a pulse with an amplitude equal to the proportional limit. This example demonstrates one reason for the existence of a highly nonuniform strain distribution in a member subjected to impulsive loading.

This simple model of propagation of stress and strain under impact conditions is essentially a one-dimensional concept, since the waves have been assumed to propagate along a bar whose cross-sectional dimensions are small compared with its length. In most actual cases it is necessary to consider three-dimensional expansion of these waves in a spherical pattern. Under these circumstances, the amplitude of any such wave is attenuated due to dilatation, whether or not its initial peak stress exceeded the elastic limit. Such a condition, in which the elastic limit has not been exceeded, is graphically represented in Fig. 5. A condition of this kind has not yet been quantitatively analyzed, and consequently most theoretical comparisons for impact conditions are based on one-dimensional considerations.

Consider now the case of reflection of a compression wave from a free end, as illustrated in Fig. 6. Initially, at the instant of reaching the free end, the compression wave will generate a tensile reflected wave of equal magnitude in order to satisfy the condition of zero stress at the free surface, but without a tail. Upon passing through the interface, the compressive wave will continue to generate the tail of the tensile reflected wave which, in the meantime, will propagate back into the medium. The material itself will experience the effect of the sum of the two waves, shown in the second diagram of Fig. 6. The forward portion of the stress diagram will be of tensile nature, since here the tail of the compression

Fig. 5 — Spherical Expansion of a Shock Wave When Elastic Limit Is Not Exceeded



wave will combine with the head of the reflected tensile wave which has a higher stress. In the rear portion the inverse of this will take place. Finally, the compressive wave will have passed in its entirety through the interface and the resulting stress condition in the bar will be entirely of tensile nature.

John Rinehart of the Naval Ordnance Testing Station, Inyokern, Calif., has applied this analysis to metal cylinders subjected to a contact explosion. With a sufficient quantity of explosive, the cylinders exhibited a pronounced bulge at the free surface which, upon sectioning, yielded an extremely brittle failure with pronounced cracks normal to the direction of wave propagation. The first and most severe crack had a characteristic thickness, and the assumption of a likely shock wave profile permitted the calculation of a tensile stress in the superposed wave pattern at which the metal failed. Additional fissures can likewise be explained in terms of further reflections resulting in superposed tensile waves in excess of the dynamic ultimate tensile stress of the material, since, of course, these metals cannot fail in pure compression.

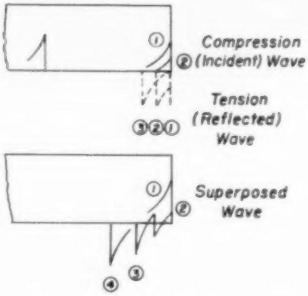


Fig. 6 — Reflection of a Compressive Wave From a Free End

PARTICLE VELOCITY MEASUREMENTS

The particle velocity that is induced by the shock wave at the free end has been measured by metal disks of the thickness of these scabs inserted loosely into a hole drilled into the cylinder. Ideally, these pellets should be ejected from the bore with the velocity of the particles at the successive free edges. Their actual velocity can be measured readily by means of high-speed photography and the stress computed by theoretical considerations. In spite of the limitations of the analysis and some possibilities of interference of surface effects at the interface between the pellets and the cylinder, good agreement has been obtained between the stresses so determined and published data concerning the ultimate tensile strength of the metals employed.

In order to obtain more accurate information concerning the particle velocity at the free surface of such a cylinder, an optical technique has been devised which records the time history of the surface distortion (and thus particle velocity) of such cylinders by an extremely high-speed camera. The technique will yield also the velocity of expansion of the wave across the surface and this can readily be converted into the propagation velocity of the wave. It has also been suggested that the free surface pressures might be measured by means of piezo-electric gages of barium titanate, which would then complete the measurement of variables required for a complete reconstruction of the shock process. With the use of cylinders of various thicknesses, the shock process can be extrapolated into the interior of the cylinder, and the measurements will then provide a sound basis for the initiation and comparison of a three-dimensional shock propagation theory for various metals.

Experiments employing the internal detonation of hollow cylinders also result in fissures and cracks which can be rationalized in terms of maximum normal tensile stresses by theoretical considerations similar to those explained above. The striking of projectiles and their possible subsequent penetration are a further interesting application of this type of analysis.

In conclusion, I would like to state that the possibilities of exploiting the concepts of shock propagation in metals are limitless, both with respect to industrial and military applications. It will be necessary to obtain indisputable data concerning the properties of various materials under dynamic conditions and to further develop shock propagation theories in order to take account of attenuation due to expansion, as well as obtain a solution to the more complex reflections involving the action of both shear and surface waves.

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

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How VANADIUM improves engineering steels and helps conserve critical alloys

In these critical times when many alloying materials are scarce, you may be able to use vanadium to good advantage. Steels alloyed with vanadium meet most of the mechanical specifications for low-alloy engineering and structural steels. In fact, vanadium can often be used in engineering steels to replace at least part, if not all, of certain alloys now in critical supply.

The metallurgy of vanadium is well known. Small additions of vanadium—0.10 to 0.30 per cent—can be used effectively to give steel extra strength, toughness, and resistance to fatigue and wear. It improves engineering steels by increasing their yield strength without sacrificing ductility. The uniformly fine grain size of vanadium-bearing steels makes them tough and resistant to abrasion, fatigue, and impact.

Better Mechanical Properties

In the following table are typical analyses for carbon-vanadium and chromium-vanadium steels that are suitable for most applications where low-alloy, high-strength steels are required. The carbon-vanadium steel is compared with plain-carbon steel; and the chromium-vanadium steel, with chromium-molybdenum steel. Note the excellent properties of the vanadium-bearing steels.

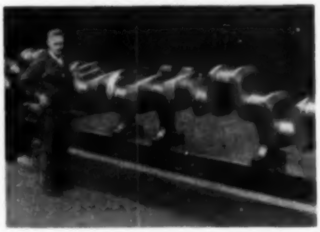


Fig. 1 — Vanadium increases the strength, toughness, and wear resistance of engineering steels for many machine parts, such as this large crankshaft.

Improves Cast Iron

A small addition of vanadium, usually from 0.10 to 0.25 per cent, refines the grain of cast iron, and materially increases its strength and hardness. Moreover, vanadium may be used in cast iron to replace at least part, if not all, of certain alloys that are now in short supply.

Vanadium in Rimmed Steel

An addition of approximately 1 lb. of vanadium per ton of steel produces non-aging characteristics in a rimmed steel. These non-aging properties, together with improved deep-drawing characteristics and the good surface inherent in rimmed steels, make these steels of particular interest at the present time.

Grades of Ferrovanadium

ELECTROMET produces ferrovanadium containing 50 to 55 per cent vanadium for the production of vanadium-bearing steels and irons. The alloy is produced in three grades with maximum 0.20, 0.50, or 3.00 per cent carbon and maximum 1.50, 2.00, and 8.00 per cent silicon, respectively. Each grade is specially adapted to fill the different requirements of iron- and steel-making.

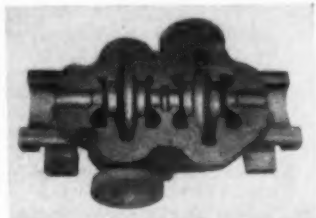
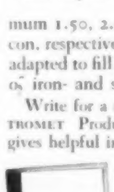


Fig. 2—Steel and iron castings treated with small additions of vanadium have high ductility and greater toughness and impact resistance.

Write for a copy of the booklet, "ELECTROMET Products and Service," which gives helpful information about the use of ferrovanadium and other alloying metals that ELECTROMET supplies. The booklet may be obtained from any ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.



Properties of Vanadium Steels Compared With Other Engineering Steels

Typical Analysis, %	Carbon Steel	Carbon-Vanadium Steel	Chromium-Molybdenum Steel	Chromium-Vanadium Steel
Vanadium	—	0.16	—	0.16
Carbon	0.50	0.49	0.50	0.50
Manganese	0.71	0.77	0.80	0.79
Silicon	0.19	0.15	0.30	0.31
Chromium	—	—	0.95	0.98
Molybdenum	—	—	0.20	—
Annealed and Furnace-Cooled				
Tensile Strength, psi	90,600	100,000	100,000	99,500
Yield Point, psi	48,900	66,000	50,000	64,100
Elongation in 2 in., %	23.3	25.0	23.0	28.4
Reduction of Area, %	37.8	49.1	45.0	59.0
Izod Impact, ft.-lb.	13.5	26.0	17.0	44.0
Quenched and Tempered				
Tensile Strength, psi	134,900	134,500	232,000	232,800
Yield Point, psi	110,800	128,000	214,500	224,200
Elongation in 2 in., %	18.3	18.3	10.0	10.4
Reduction of Area, %	54.1	56.6	39.0	43.1
Izod Impact, ft.-lb.	54.0	65.0	12.0	12.0

Personal Mention

Oliver Smalley

Harold L. Maxwell

OLIVER SMALLEY ⊕, one of the early workers in the manufacture of basic electric steel and manufacture of steel direct from iron ore, started his career at the age of 23 as director of the laboratories of Messrs. W. G. Armstrong Whitworth & Co., England. During his 12 years with the company he also managed the foundry's steel works and metal recovery department, and began a long list of contributions to many technical and scientific societies, covering his researches on foundry, chemical and metallurgical subjects. In 1925 Mr. Smalley came to America where, because of their parallel interest in the development of high-strength cast iron, he joined forces with Augustus F. Meehan of Chattanooga, Tenn., to form the Meehanite Metal Corp. At the present time, besides being president of this corporation, Mr. Smalley is operating foundry activities in some 24 countries and directs associate research organizations in America, London, South Africa, Australia, and New Zealand. Under his direction these organizations have published over 550 reports on original researches and investigations in chemical and metallurgical fields, iron and steel manufacture, and foundry practices. He has made a number of discoveries in the use of rare metals, in the manufacture of superior cast irons, and in metallurgical and foundry processes.

HAROLD L. MAXWELL ⊕, recently elected vice-president of the American Society for Testing Materials, pioneered the use of the austenitic stainless steels for the construction of process equipment used in the chemical industry. His work in this field is responsible to a great extent for the standard specifications of today, and he has contributed much to the present-day knowledge of these alloys. His Ph.D. degree is in chemical engineering and chemistry from Iowa State College. He spent the first four years of his professional career as associate professor of chemical engineering at Purdue University. In 1930 he became consulting metallurgist with the E. I. duPont de Nemours & Co., and after three years with the ammonia department, he organized a research group at the DuPont Experimental Station at Wilmington, Del., to work on materials of construction, directing this expanding group until 1946. He has participated in the activities of many scientific and engineering societies, and encourages young professional men to affiliate with technical societies to supplement their professional training. He is currently supervisor of approximately 60 consultants in the DuPont engineering department, and participates actively in the engineering phases of development, design, construction, and maintenance of chemical plants.

Eric Gregory ⊕ has completed three years of research work in England on the effect of internal oxidation on high-temperature properties of certain silver alloys and has been awarded an Economic Cooperation Administration scholarship to study production technology of high-temperature materials in America.

Warner N. Pierson ⊕, resident engineer with the Norge Division of Borg-Warner Corp., Chattanooga, Tenn., for the past five years, has recently accepted a position as metallurgist on guided missile development at the Redstone Arsenal, Huntsville, Ala.

T. I. McClintock ⊕ has been transferred from the New Kensington (Pa.) Works of the Aluminum Co. of America to the company's central Metallurgical Division, Pittsburgh, as staff metallurgist.

Richard R. Brady ⊕ has accepted a position as plant metallurgist for Steel Shot Producers, Inc., Butler, Pa., a subsidiary of the Pittsburgh Crushed Steel Co.

H. F. Walker ⊕, formerly plant metallurgist at General Motors Corp.'s Transmission Division, Muncie, Ind., is now chief metallurgist in the engineering division at the Chevrolet Aviation Engine Plant, Tonawanda, N. Y.

Elliott Willner ⊕, who graduated from the Montana School of Mines last June, is now working as a trainee at the Federated Metals Division, American Smelting & Refining Co., Whiting, Ind.

Donald A. Cogley ⊕ has taken a position as metallurgical assistant at Timken Roller Bearing Co., Canton, Ohio.

R. M. Dyke ⊕, formerly active in technical-vocation education in British Columbia and Alberta, has joined the editorial staff of *Machine Production* magazine, Toronto, Ont., as associate editor.

Robert B. Boswell ⊕ has been appointed supervisor of chemical and metallurgical laboratories of the new Chrysler Tank Engine Plant, New Orleans. He was formerly a research metallurgist at the Chrysler Corp.'s Central Engineering Division, Highland Park, Mich.

Personals

George Stern ⊕ and **Richard P. Seelig** ⊕ have been elected vice-presidents of the American Electro Metal Corp., Yonkers, N. Y.

Fred Stirbl ⊕, who recently completed a special Air Force assignment, has taken a position as consulting research metallurgist associated with the research and development department, Arma Corp., Brooklyn.

E. Russell Meyer ⊕ has recently transferred from his position as assistant chief inspector at the Caterpillar Tractor Co., Peoria, Ill., to that of manager of quality, Eureka Williams Corp., Bloomington, Ill.

Richard E. Grace ⊕, a June graduate of Purdue University, has enrolled as a graduate student in the department of metallurgy, Carnegie Institute of Technology, Pittsburgh, where he also holds the position of research assistant.

The American Welding Society, New York, has recently made the following announcements:

Robert S. Green ⊕, associate professor and chairman of the department of welding engineering at Ohio State University, Columbus, has been elected a director of the A.W.S.

Alexci P. Maradudin ⊕, metallurgist and materials engineer, Standard Oil Co. of Calif., has been elected vice-president, Western District, of the A.W.S.

I. O. Oehler ⊕, director of metallurgy and research, American Welding & Manufacturing Co., has been elected a director-at-large of the A.W.S.

Ernest F. Nippes ⊕ and **John N. Ramsey** ⊕ have been selected the winners of the first prize for their paper "Spot Welding of Scaly Heavy Gage Structural Steel". This prize is for the best papers from a university source. Dr. Nippes, with co-authors **J. M. Gerken** ⊕ and **J. G. Maciora** ⊕, also won the second prize for the paper "The Projection Welding of 0.010 and 0.020 in. Steel Sheet".

T. B. Jefferson ⊕, editor of the *Welding Engineer* and the Welding Encyclopedia, McGraw-Hill publications, has been elected vice-president of the Mid-Western District of A.W.S.

W. H. Bruckner ⊕, research associate professor of metallurgical engineering, University of Illinois, received the 1951 Lincoln Gold Medal awarded by the A.W.S. annually to the author of the paper judged to be the greatest contribution to the advancement and use of welding for the year.

Eric R. Seabloom ⊕, supervisor of field engineering, Crane Co., Chicago, has been elected second vice-president of the A.W.S. for 1952.

Donald C. Taylor ⊕ and **Clee O. Worden** ⊕ have been appointed assistants to the sales managers of tool steels and machinery steels, respectively, by the Horace T. Potts Co., Philadelphia.

Edward Epremian ⊕ has been employed as liaison metallurgist with the London Branch, Office of Naval Research, Schenectady, since his graduation from Carnegie Institute of Technology last June.

J. H. Roach ⊕, formerly located at the Tulsa, Okla., office of Babcock & Wilcox Tube Co., has been transferred to the Houston, Tex., office and named assistant sales manager.

Personals

George W. Frick was recently appointed assistant sales manager for Latrobe Electric Steel Co., Latrobe, Pa.

Andrew E. St. John has been elected vice-president and treasurer of Alloys and Products Inc., New York. In addition to his official duties he will be in charge of the company's manufacturing operations.

William C. Blakely has been employed by the Ohio Ferro-Alloys Corp., Pasadena, Calif., as a sales representative.

Solomon Musikant, formerly with the Sandia Corp., Albuquerque, N. M., has accepted a position as head of the development division with the Vibradamp Corp., Los Angeles.

V. H. Gallichotte has accepted a position as design engineer of electronic equipment for the Sierra Electronic Corp., San Carlos, Calif.

M. N. Ornitz and **R. C. Enke** have been appointed works manager and general superintendent, respectively, of National Alloy Steel, division of Blaw-Knox Co., Blawnox, Pa.

Harry Schwartzbart, research metallurgist for the National Advisory Committee for Aeronautics, Cleveland, since 1948, has been appointed a research metallurgist in the metals research department at Armour Research Foundation of Illinois Institute of Technology, Chicago.

M. L. Killgallon has recently been transferred to the Berry Division of Oliver Iron and Steel Corp., Corinth, Miss., where he is plant manager.

Hugo R. Larson, who received his Ph.D. degree from Massachusetts Institute of Technology in September, is presently located in Sweden doing research work under a M.I.T. grant.

Nathaniel B. Green has been transferred from the Los Angeles Division to the Columbus (Ohio) Division of North American Aviation Inc., where he is assistant laboratory director in charge of processing in the production development laboratory.

Walter W. Koenig has recently taken a position in General Electric Co.'s Turbine Division, Schenectady.

Richard A. Weaver has recently taken a job as assistant to the production metallurgist at Cleveland Twist Drill Co., Cleveland.

W. J. Riley, formerly quality control engineer at the Canadian General Electric Co. (Montreal Works) has been appointed division engineer of the Refrigerator Division, Montreal.

Willis L. Schalliol has been made head of the research and development group in the metallurgy section at General Electric Co.'s Hanford Works, Richland, Wash.

Robert A. Roth is now employed as a field engineer in the photo products department, E. I. du Pont de Nemours & Co., Inc., Parlin, N. J.

Melvin A. Buettner has been employed by the National Lead Co., Fredericktown, Mo., since his graduation from Missouri School of Mines in June.

Personals

Warren M. Parris, formerly employed as a metallurgist with the Climax Molybdenum Co., Detroit, has taken a position with Battelle Memorial Institute, Columbus, Ohio, in the same capacity.

Paul M. Winslow, formerly resident chief metallurgist of the Des Moines (Iowa) plant, Solar Aircraft Co., is now chief metallurgist for the Harvill Corp., Los Angeles.

J. R. Hamilton has been made senior service metallurgist for the railroad materials and commercial forgings department, U. S. Steel Co., Chicago.

James W. Aittama, formerly plant metallurgist at the Wisconsin Axle Division of Timken-Detroit Axle Co., is now chief metallurgist for the Johnson Motors Corp., Waukegan, Ill.

Earl M. Mitchell recently started the Mitchell Smelting and Refining Co., Botsford, Conn., for the production of brass and bronze ingot metal for the foundry trade.

Jay Bland, formerly senior welding engineer in the metallurgical laboratory, New York Naval Shipyard, Brooklyn, is now senior project engineer in the engineering research department, Materials Division, Chicago, Standard Oil Co. of Indiana.

Kenneth L. Kojola has been employed as a materials engineer at the U. S. Naval Gun Factory, Washington, D. C., since his graduation from Michigan College of Mining and Technology in June.

Raymond A. Robic has recently been appointed council coordinator of small industries for the Quebec district in the Department of Defense Production, Canada. He will retain his position as director of the firm of Marion & Marion, patent attorneys.

James D. Bean has taken a position as assistant plant metallurgist at the John Deere Ottumwa Works in Ottumwa, Iowa. He was formerly associated with Deere & Co., Moline, Ill.

James H. Keeler, who recently finished his work at Pennsylvania State College, is now connected with General Electric Co.'s Research Laboratory, Schenectady, as a research associate.

From Bumper to Tailgate . . .
N-A-X
HIGH-TENSILE STEEL
Reduces Deadweight and Increases Durability
The widespread use of N-A-X HIGH-TENSILE steel in transportation equipment emphasizes two vital characteristics of this high-strength low-alloy steel.
1. *Strength with less deadweight.* N-A-X HIGH-TENSILE steel reduces deadweight . . . of great importance in transportation equipment and military vehicles.
2. *Exceptional durability.* N-A-X HIGH-TENSILE steel, with its high strength and toughness, has proved greater resistance to fatigue and impact at normal and sub-zero temperatures. Its inherent structure and composition greatly reduce the effects of abrasion and corrosion.
The response of N-A-X HIGH-TENSILE steel to severe cold-forming operations and its excellent weldability by electric arc or resistance, atomic hydrogen or heliarc, and all other processes, are added important characteristics of N-A-X HIGH-TENSILE steel.
SCRAP
STEEL
A.F.F. BOARD NO. 2
TEST OPERATION
The "Eager Beaver"
The use of low-alloy, high-strength steels in military equipment assures longer life with less deadweight.
GREAT LAKES STEEL CORPORATION
N-A-X Alloy Division • Ecorse, Detroit 29, Michigan
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NATIONAL STEEL

Carbon Lining for Blast Furnaces*

TEN YEARS' EXPERIENCE with carbon refractories in the blast furnaces at Appleby-Frothingham plants of the United Steel Companies, Ltd., of England, have shown that the many hearth breakouts and scaffolding which occurred in these furnaces when lined with high-alumina fireclay bricks have been corrected. In ten years with carbon hearth linings only one breakout was encountered; this compared to 23 breakouts in the previous 14 years on the same furnaces with fireclay brick hearths.

The carbon blocks have much greater strength at all temperatures above 2550° F.; they resist abrasion to a greater extent; they are resistant to chemical attack by the reducing gases, molten slag and molten iron, whereas the fireclay bricks are affected by all of these; they have thermal conductivity three times greater than fireclay, thus giving much more efficient cooling in the hearth and bosh sections; they are not wetted by molten slag and molten iron, which greatly reduces erosion.

The success of the carbon hearth led to a trial in the bosh of two furnaces in 1945. Both furnaces operated successfully with a 13½-in. carbon brick bosh lining for four years and, at the end of the campaign, there was no deterioration of the lining. The high thermal conductivity, high abrasion resistance and nonwetting properties are believed to be the main contributing factors. Use of carbon blocks in hearth and bosh linings is now standard practice on all of the company's 11 blast furnaces.

A carbon lined tap hole for iron gave trouble; it was oxidized by air and water during tapping periods. This trouble was corrected by installing a fireclay iron notch which is plugged with fireclay by the mud gun after each tap. The standard water cooled copper casting set into the carbon refractory is entirely satisfactory for the slag notch.

Exploratory installations in the upper stack over a period of eight years showed that the carbon blocks were much superior to fireclay in this region, also. Here the resistance

(Continued on p. 108)

*Abstract of "The Evolution of the All-Carbon Blast Furnace", by J. H. Chesters, G. D. Elliot, and J. MacKenzie, *Journal* of the British Iron & Steel Institute, Vol. 167, March 1951, p. 273.

SAVE SHOP LABOR SHOP TIME GRINDING COSTS

STRESSPROOF PROVIDES

4 QUALITIES IN 1 BAR

1. Eliminates Heat Treating
Its *in-the-bar* strength, as received, is twice as great as ordinary cold-finished steel shafting.

2. Eliminates Case Hardening
Its resistance to wear, as machined, is sufficient to replace many heat-treated or carburized steels.

3. Minimizes Warpage
Because it is *stress-relieved*, this superior bar assures the user a minimum of distortion.

4. Speeds Up Machining
Has *in-the-bar* machinability fully 50% better than heat-treated alloys of the same hardness.

Many companies are realizing important savings by using Ground and Polished STRESSPROOF bars instead of grinding the steel in their own shop. For this superior steel provides precision tolerances at a reasonable cost, without tying up valuable labor and machinery.

This all-purpose bar stock is ground to close tolerance and highly polished at the LaSalle plant on batteries of modern machines — at lower cost than you can grind it yourself. Furthermore, because this versatile steel is stress-relieved, it requires no straightening after keyseating, journaling, threading, or other machining operations. And its four qualities in-the-bar eliminate many other costly operations.

Almost all of today's Ground and Polished STRESSPROOF production is going into defense jobs. However, from time to time, some sizes of sample bars may be available for testing purposes.

La Salle STEEL CO.
1424 150th Street, Hammond, Indiana

Carbon Lining for Blast Furnaces

(Continued from p. 106)

of the carbon blocks to wetting by the semimolten materials prevented scaffolding, and the lining life was improved. Consequently in 1949 one furnace was completely lined with carbon refractories. This furnace had 5 ft. of special keyed shape carbon blocks on the hearth bottom, hearth side walls with a 2-ft. thickness of standard shaped carbon bricks surrounded by cooling plates, and a bosh lining of 9-in. carbon bricks. The stack was lined with standard shaped carbon bricks to a thickness varying upward from 2 ft. at the mantel to 3 ft. at the top. A second furnace was built with all-carbon lining in September 1949; it was insulated by an outer wall of vermiculite brick and powdered vermiculite against the shell. The shell temperature was thus reduced to about 200° F.

Both these furnaces have operated successfully since blowing-in in 1947. The first furnace has produced a daily average of 12% more iron and the second 4% more than in previous campaigns, without any trouble from scaffolding and breakouts.

In spite of the much higher initial cost the economic advantages of the carbon bricks are all favorable. Some of these are:

1. Thinner lining with larger furnace volume
2. No drying out period on new lining
3. Much longer campaign life
4. Reduction of breakout and scaffolding troubles
5. Greater tonnage output
6. Simpler furnace construction

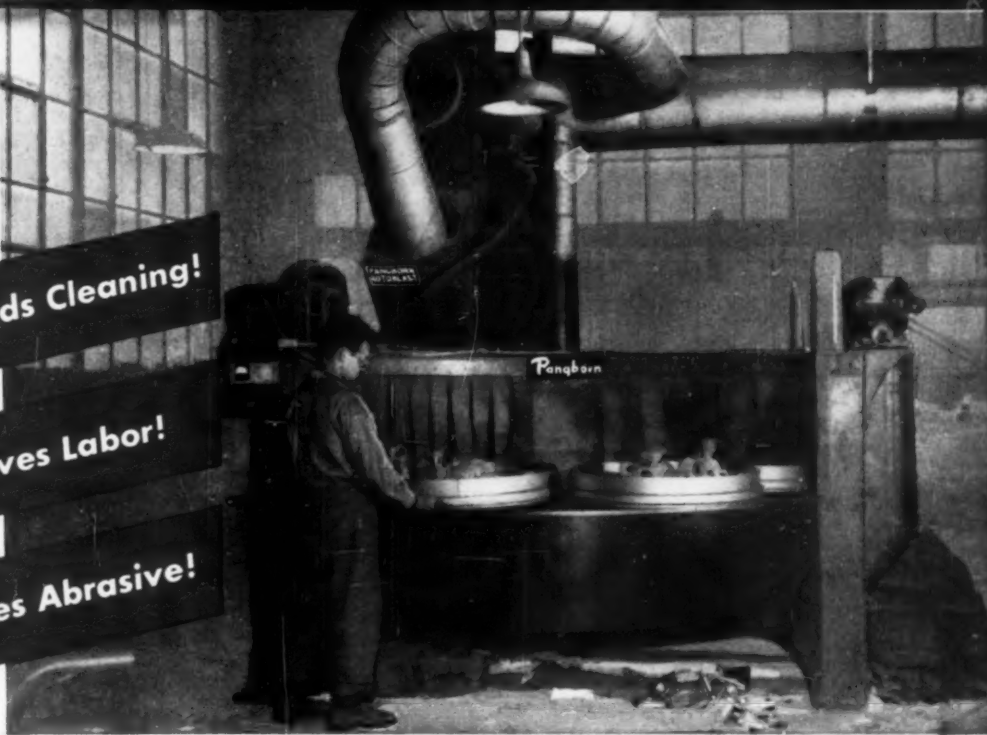
These results are based entirely on the smelting of lean British ores with resultant large slag volumes; the advantages claimed may not accrue to American furnaces.

Aging of Al-Cu Alloys*

This paper presents the first part of a fundamental investigation of the aging process in Al-Cu alloys. The objectives were: *(a)* to determine aging curves at different temperatures for alloys with various copper contents; and *(b)* to deduce

(Continued on p. 110)

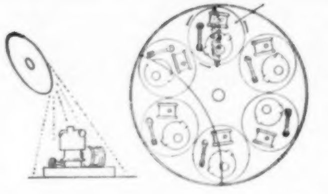
*Abstract of "The Aging Characteristics of Binary Aluminum-Copper Alloys", by H. K. Hardy, *Journal*, Institute of Metals, Vol. 79, 1951, p. 321-369.



Read how this Pangborn "LG" ROTOBLAST* Table CUTS CLEANING COSTS by $5556.00 A YEAR

PROFITABLE BLAST CLEANING! That's the story at the Anstice Co. in Rochester, N. Y. Their Pangborn "LG" ROTOBLAST Table shown above has cut labor costs by $2540.00 a year—even though tonnage has increased! In addition, abrasive costs have been cut by $3016.00 a year because ROTOBLAST makes full use of long-lasting Malleabrasive grit (it can be used for up to 300 passes!) As Ken Proud, Foundry Manager sums it up: "We are more than satisfied with results!"

You'll be more than satisfied with



Pangborn "LG" ROTOBLAST Tables too because they're designed for fast, low-cost cleaning of intricate and fragile work. As shown above they clean *completely* because abrasive is hurled at a 45° angle to the work. And *uniform* cleaning is assured because auxiliary tables revolve castings under blast stream.

No matter what you clean, Pangborn has a standard ROTOBLAST Table designed for your job. Included in the standard line are *Turn-Style* Tables for bulky castings . . . and *Table-Rooms* for jobbing work. For full information on the right Pangborn ROTOBLAST Table for your job, write to: PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md.

ROTOBLAST . . .

SAVES LABOR with push-button operation

SAVES SPACE because machines are compact

SAVES TIME by cleaning more loads per day

SAVES POWER since no compressor is needed

SAVES TOOLS because all scale is removed

Look to Pangborn for the latest developments in Blast Cleaning and Dust Control equipment.

Pangborn

BLAST CLEANS CHEAPER

with the right equipment for every job

*Trademark of Pangborn Corporation

Aging of Al-Cu Alloys

(Continued from p. 108)

hypotheses to explain the aging process.

High-purity sheet (0.22 in. thick) of five Al-Cu alloys with copper contents of 2.0, 3.0, 3.5, 4.0 and 4.5% was prepared by cold forging. To determine the aging curves, small specimens of the cold forged sheet were first heat treated at a temperature high enough to dissolve all the copper in each of the alloys. Following the heat treatment, the specimens were quenched in cold water to form a supersaturated solid solution of copper in aluminum. Within 5 min. after heat treatment, the specimens were put into the various aging furnaces. Specimens from all five alloys were aged at 85, 265, 330, 375 and 430° F.; specimens from the 4.0% copper alloy were also aged at 465° F. The course of the precipitation of copper-rich phases from the supersaturated Al-Cu solid solutions was determined by making Vickers pyramidal-diamond hardness measurements upon specimens removed from the furnaces after periods ranging from a few minutes to several hundred days.

The hardness values for each alloy at each temperature were plotted against the logarithms of the aging periods. The aging curves obtained in this way were of two types, one termed "single-stage", the other termed "two-stage". During the earlier periods of aging, both types of curves remained nearly flat, reflecting constant hardness values. After a certain period (maximum 18 days, but usually only a few minutes or a few hours), termed the "incubation period", both types of curves began to rise, reflecting the gradual age hardening of the alloys. Each single-stage curve rose continuously beyond its incubation period, reached a peak hardness value and then fell continuously. Beyond its incubation period, each two-stage curve rose continuously, halted almost abruptly and flattened for the second time, reached a second incubation period, rose continuously again, reached a peak hardness value and then fell continuously. With a few exceptions, the parts of the curves up to the peak values could be represented reasonably well by straight lines. The exceptions probably represented conditions under which both types of curves were obtained simultane-

(Continued on p. 114)

"EDCO Dowmetal BOTTOM BOARDS have resulted in tremendous savings for our foundry"

... says M. C. Crawford of
RILEY STOKER CORPORATION

RILEY STOKER CORPORATION
FUEL BURNING AND STEAM GENERATING EQUIPMENT
301 WALKER STREET, DETROIT 7, MICH.

Christiansen Corporation
1515 North Kilpatrick Ave.
Chicago 51, Illinois

May 16, 1951

Attn: Mr. Edw. S. Christiansen, Pres.

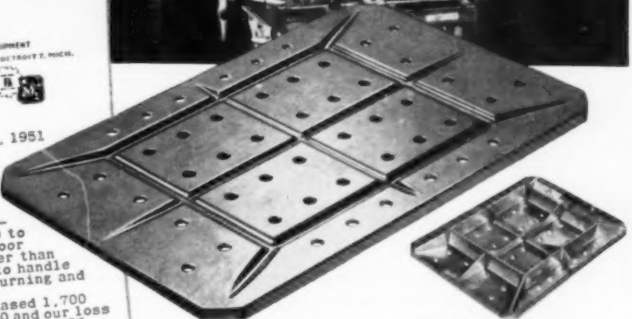
Gentlemen:

Before the purchase of EDCO Dowmetal Bottom Boards, we made our own wood boards at a cost of approximately 70c each. We would make 5,000 to 6,000 per year and ended up with a poor quality board. They were much heavier than EDCO magnesium boards, not as easy to handle on the line, and our losses due to burning and breakage were 60 to 80% per year.

In three years time, we have purchased 1,700 of your boards at a cost of $7,585.00 and our loss in this period has been only $207.36 or 2.73%.

EDCO Dowmetal Bottom Boards have resulted in tremendous savings for our foundry. It is a pleasure to recommend them to other foundries.

Yours very truly,
RILEY STOKER CORPORATION
M. C. Crawford
M. C. Crawford
Director of Purchases
Detroit Plant



Above photo shows molder at Riley Stoker Corporation placing EDCO Bottom Board on flask preparatory to pressing. EDCO DOWMETAL magnesium boards maintain high quality of castings and reduce rejects because the exclusive grooved and vented design permits escape of gasses and insures mold stability.

Riley Stoker Corporation is one of the three largest manufacturers of steam generating and fuel burning equipment in the country. EDCO DOWMETAL Bottom Boards are used exclusively in their foundry in the production of gray iron and alloyed casting components.

Photo at left shows molder pouring sand into flask. Photo at right shows molten metal being poured into molds which rest on EDCO Bottom Boards. Gravity conveyor line carries molds on for further processing.

Progressive foundry operators, like Riley Stoker Corporation, are equipping their foundries with EDCO DOWMETAL Bottom Boards.

Made of magnesium, these boards will not warp or break. There are no nails to come out, nothing to break or split—no upkeep! So durable, they can be considered permanent equipment. The many advantages from the use of these boards are effective immediately on their installation.

Write us or phone CApitol 7-2060 today for complete price schedule and list of 74 standard sizes available from stock.

EDCO
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CHRISTIANSEN CORPORATION
1519 N. KILPATRICK AVE. • CHICAGO 51, ILLINOIS
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Reynolds
ALUMINUM REPORTER
A SERVICE TO INDUSTRY ON ALUMINUM USES AND DEVELOPMENTS

LOUISVILLE 1, KY.

NUMBER 6

NEW MECHANICAL FASTENING METHODS BOOKLET

Latest Data on Various Types of Mechanical Joints and Fasteners Now Available Upon Request

The Technical Editorial Service of the Reynolds Metals Company has produced a new technical book, "Mechanical Fastening Methods for Aluminum."

As stated in the foreword, "In addition to welding, brazing and soldering, a wide variety of mechanical fastening methods are used to join assemblies involving aluminum parts. This book represents an endeavor to supply the designer and manufacturer with data on the various types of mechanical joints and mechanical fasteners for use with aluminum."

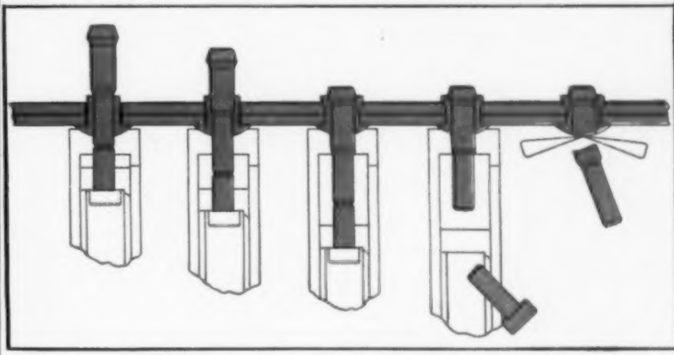


Diagram showing cross-section of method for fastening with self-plugging blind rivets. This is typical of the many explanatory illustrations found in Reynolds newest technical book, "Mechanical Fastening Methods for Aluminum."

Containing all you need to know about fastening aluminum components, this 136-page illustrated booklet is a *must* for your desk reference library. Its handy pocket size makes it ideal for easy carrying and ready accessibility in the shop.

There are tables of related data for the various types of standard rivets, including dimensions and number of pieces per pound, lengths of rivets for cone-point and button-type driven heads, recommended hole sizes with shear and bearing areas for both hot and cold-driven rivets, and maximum loads for single rivet in shear.

You will find in this book answers for your questions on standard and special rivets, standard and special screw fasteners, nails and pins, metal stitching, mechanically formed joints, resin bonding and others.

Illustrated above is an example of one of the complete diagrams explaining the method of riveting, using self-plugging blind rivets.

Application of the latest 1951 fastening methods like these means increased production capacity and lower costs for every type of aluminum assembly.

The Reynolds Metals Company states in the book that they will be glad to grant permission to any technical writers to use transcripts from the book. Also, technical writers and editors may obtain glossy 8 x 10-inch photoprints of any of the book's illustrations.

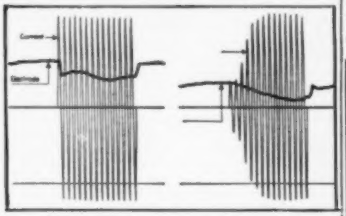
For manufacturers or designers having a special development problem not covered by this book, Reynolds offers the services of its trained staff of aluminum specialists. Let them show you how to overcome difficulties and set up for fast, economical production. For prompt service, call the Reynolds field office listed under "Aluminum" in your classified telephone directory.

(A reprint of the book's riveting section, the most important mechanical joining method, is available in quantities for distribution to students in schools, colleges and technical groups without charge.)

For your *free* copy of the valuable handbook described above, plus a complete index of Reynolds technical literature, write on business letterhead (otherwise price is $1.00) to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

New Control System Extends Electrode Life 20-30 Times When Spot Welding Aluminum

A new system called "slope control", that extends electrode life 20-30 times when spot welding aluminum with ordinary alternating current welders, has been developed by General Electric and is recommended by Reynolds Metals Company technical staff.



Tip-pressure tracing without (left) and with (right) "slope control"

The new control system restricts the flow of welding current during the first few cycles, allowing the welding current to build up gradually to maximum. This reduces softening of metal under the electrode tip, helps maintain tip pressures, and holds down tip temperatures, thus reducing "sticking" almost to the vanishing point.

In certain oscillograph curves traced during the testing of this system, total amount of heat produced at electrode tips was seen to be something less than one-sixth the usual amount, cutting tip temperature rise tremendously.

For further information on this new system, write for your free copy of the Reynolds Technical Advisor No. 15. Any engineer, designer or executive who requests it on business letterhead will be placed on the mailing list to receive copies of the "Advisor" as issued.

For assistance on any *special* production problem, call on the trained staff of Reynolds Aluminum Specialists ready to help you overcome difficulties and obtain maximum benefits from your aluminum. Call the Reynolds distributor listed under "Aluminum" in your classified telephone directory, or write to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

Reynolds Building Largest Gas-Burning Electric Power Plant

To supply the tremendous electric power requirements in its new 80 million dollar aluminum reduction plant at Corpus Christi, Texas, the Reynolds Metals Company is installing 78 internal combustion engines totalling 256,300 horsepower and driving direct-current generators with a total rated output of 176,000 kilowatts. Using natural gas for fuel, it will be the largest gas-burning engine plant so far built anywhere in the world.

MORE INTERESTING NEWS ABOUT ALUMINUM ON NEXT PAGE

Printed in U. S. A.

Aluminum Pipe Makes Portable Sprinkler Irrigation Reality

Use of portable sprinkler irrigation systems on American farms has grown spectacularly since 1945. One of the largest factors causing this increase has been the tremendous advantage of aluminum irrigation pipe.

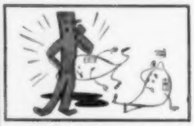
Extreme portability due to light weight, great strength offering high pressure resistance, plus rust and corrosion resistance . . . all these contributed to the demand for aluminum irrigation pipe and made *portable* sprinkler irrigation a reality.

During the present emergency, aluminum pipe of this type is being used as the basic component of the "Superbazooka", the 3.5 inch rocket-launcher. If you can find a use for extruded aluminum tubing in the design of your future products, call the Reynolds Aluminum Specialist . . . let him work with you to assure the maximum benefits of aluminum. His development and research skill is backed by the experienced staff of the Reynolds Technical Service. For further information call the Reynolds distributor listed under "Aluminum" in your classified telephone directory. Or, write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

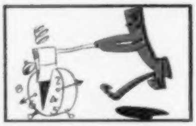
New Idea for Artists' Medium

Swiss experiments indicate that ⅛-inch aluminum, coated with a porous oxide skin, provides a practical and permanent working foundation for oil painting. It doesn't tear, split or wrinkle like canvas and takes less storage space. The smooth surface paints easier, gives more brilliant colors.

Shippers of Defense Material Find Nothing Protects Like Aluminum Foil

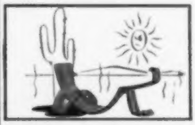


Keeps Moisture Out — Reynolds Plain Aluminum Foil is a positive barrier against transmission of moisture vapor. In gauges .0015" and heavier, it has a zero moisture-vapor-transmission rate.



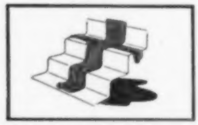
Cuts Packaging Time — Reynolds Plain Aluminum Foil offers maximum conformity to the object to be packaged. Shapes easily by hand. No valuable time lost tying, binding or taping.

Naturally Greaseproof — Reynolds Plain Aluminum Foil prevents greases on parts from drying out or hardening, thereby losing their value. Aluminum is naturally greaseproof on both sides.



Maintains Top Efficiency Indefinitely — Reynolds Plain Aluminum Foil does not depend on treatments for waterproof qualities, therefore it is not affected by long exposure to dry air or heat.

Absolutely Non-Absorptive — Reynolds Aluminum Foil does not absorb dipping compounds as other barrier materials do. This means a direct cash saving on the dipping material used.



No "Spring Back" — Reynolds Plain Aluminum Foil is "dead soft" and holds molded contours. Excellent for parts impractical to package by old-fashioned methods and materials.

Reynolds Pure Aluminum Foil is particularly suited as an intimate wrap for parts which have large air voids and cannot be dipped without undue bubbling. The ease with which it conforms to and holds shape leaves less "dead air space" in package.

For your copy of the FREE booklet "How, Why and When You Should Consider Protective Packaging with Aluminum Foil" write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

Aluminum Medical Chest Another Example of Reynolds Parts Fabrication Service

Complete Facilities Help Manufacturers with Military Orders

Another example of the complete and valuable service to industry performed by the Reynolds Parts Fabrication Service, these aluminum medical chests are now being produced for the Armed Forces Medical Units. The wide range of facilities available to manufacturers through the use of this service is demonstrated by the blanking, drawing, spot-welding, seam-welding, finishing and other allied operations necessary to produce this type of chest.

Formed of Reynolds .091" Aluminum, these chests have reinforced corners and welded gasket retaining channels for strength and rigidity. Flush mounted hardware allows containers to be stacked on any side. Stacked flat, the nesting feature of the design prevents sliding even when stack is tilted. Gum rubber gaskets assure water-proofing.

Shipping containers like these are only one of the many applications of the skill and production facilities of the Reynolds Parts Fabrication Service. This service provides all manufacturers with extra assembly lines when needed. Through the use of this program, the manufacturer is assured of a steady flow of inspected parts whenever needed and in whatever quantities desired. Quotations on aluminum parts can be furnished to the manufacturers' designs and specifications.

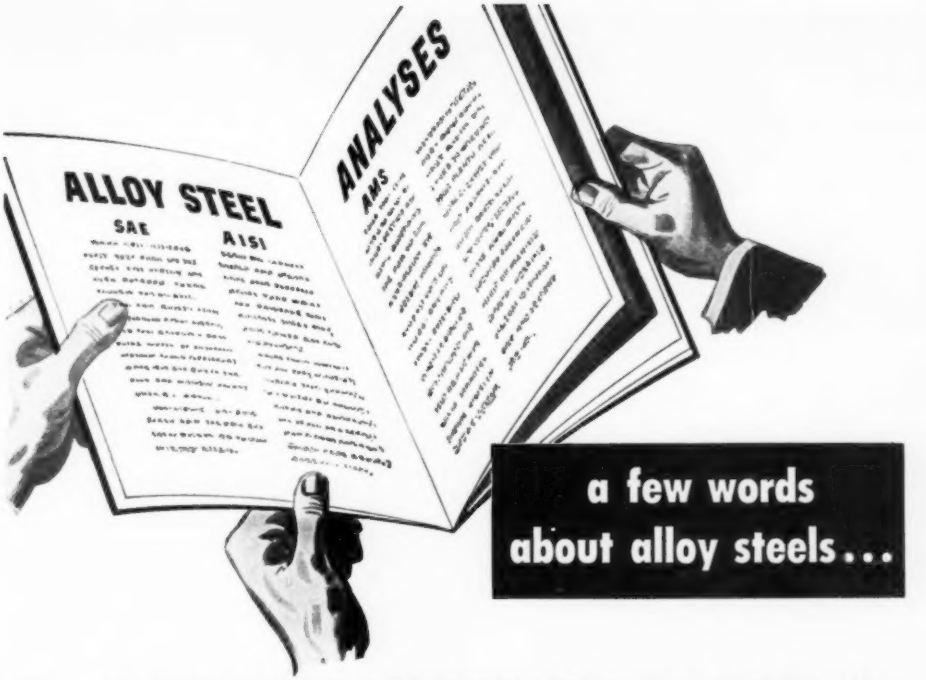
Probably one of the most important features of the Parts Fabrication Service is the tremendous savings in vitally needed scrap . . . averaging 30% and often as high as 75%! This results in savings on shipping, storing and handling charges plus making important scrap readily available for remelting at the mill. On "DO" orders where the allocation is in pounds of metal, the manufacturer gets full value from his allocation, receiving the exact number of parts available from the pounds of metal allocated.

For further information on the Parts Fabricating Service and how it can help your production, merely call the Reynolds office listed under "Aluminum" in your classified telephone directory. Or, write to Reynolds Metals Company, 2065 South Ninth Street, Louisville 1, Kentucky.

New Book Tells Complete Reynolds Aluminum Story

A new booklet has been prepared for distribution to all those interested in modern metal developments. This 45-page booklet, "Reynolds Aluminum and the company that makes it", is the first complete compilation of the facts about the company that did more than any other to bring America's aluminum production up to the point it has reached today. The booklet presents the principal operations of Reynolds Metals Company under "normal conditions" and during the present rearmament program.

Profusely illustrated and handsomely bound, the booklet is available upon request to those writing on business letterhead. Address the Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.



a few words about alloy steels...

OR...HOW WE MEET RESTRICTIONS WITH EXPERIENCE

● When you face government restrictions on any of the alloy steels you have been using, it's time to draw on the all-inclusive experience of the Republic 3-Dimension Metallurgical Service.

You and your own metallurgists will get expert assistance from the closely-coordinated Republic three-man team . . . the Field Metallurgist, the Laboratory Metallurgist, and the Mill Metallurgist. Their combined experience in solving problems of alloys, manufacture and steel processing is helping hundreds of alloy steel users make the most of currently available specialized steels.

In spite of the growing restrictions on many alloy steel analyses, you probably can switch your production to one of the many alloy steels being produced by Republic... world's largest producer of alloy and stainless steels.

Which one? . . . Ask a Republic Metallurgist.

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ALLOY STEELS

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

Aging of Al-Cu Alloys

(Continued from p. 110)

ously to some extent. The highest peak values were reached by the two-stage curves.

The curves at 85° F. were of the two-stage type, except that the second incubation period was not reached. At 265 °F. clearly defined two-stage curves were obtained for the 3.5, 4.0, and 4.5% copper alloys. A few of the curves at the intermediate temperatures were combinations of the two types. The remainder of the curves were of the single-stage type.

The single-stage curves were favored by high temperatures and low degrees of supersaturation. Conversely, the two-stage curves were favored by low temperatures and high degrees of supersaturation.

The curves are discussed with reference to a recent thermodynamic analysis of the decomposition of supersaturated solid solutions (H. K. Hardy, *Journal*, Institute of Metals, Vol. 77, 1950, p. 457). Aging in Al-Cu alloys involves the formation of four copper-rich phases called Guinier-Preston zones [1] and [2], θ', and θ. The last two phases are normal intermetallic compounds having the formula $CuAl_2$ but differing in their arrangement of aluminum and copper atoms.

As a rule, the zones form as discrete particles with discontinuities in lattice structure between them and the parent metal. The two G-P (Guinier-Preston) zones are believed to be extremely thin plate-like clusters of segregated copper atoms parallel to the cube planes of the parent metal. Usually, they remain coherent with the lattice structure of the parent metal, that is, they strain the lattice structure of the parent metal without breaking away from it and forming discontinuities. The G-P zones differ from each other in their degrees of order of copper atoms. In the G-P zone [1] the copper atoms are more or less randomly arranged while in the G-P zone [2] the atoms are arranged in a definite pattern. It is known that θ can be formed from θ', but there is not enough evidence to show whether G-P zone [1] → G-P zone [2] → θ'.

Aging is believed to occur in the following manner: The single-stage aging curves result from the formation of G-P zone [2] directly from the parent metal by a process of nucleation and growth, although θ'

(Continued on p. 116)

Aging of Al-Cu Alloys

(Begins on p. 108)

may be the initial decomposition product at a very low degree of supersaturation. The initial rise in the two-stage aging curves results from the formation of G-P zone [1]. The flat portion of these curves beyond the first incubation period is the result of G-P zone [1] in a solid solution of metastable equilibrium. The higher peak hardness values reached by the two-stage aging curves result from the presence of both G-P zones [1] and [2]. In forming G-P zone [2], the mechanism requires the dissolution of G-P zone [1]. In all instances, prolonged aging results in the formation of θ' and θ and the gradual softening of the alloy.

E. H. Hollingsworth

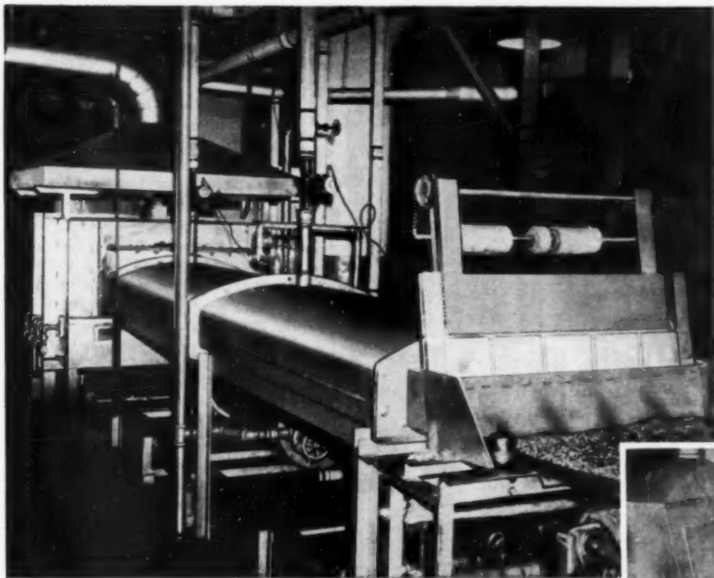
Control Methods for Sinter*

The making and use of sinter is in the state of a rapidly expanding technology. Furnace results have often been disappointing and, in general, have not lived up to the expectations of several years back. At the same time, industry has taken little or no advantage of available testing methods that would be helpful in defining more clearly the properties desirable in good sinter. Such data, when correlated to operating results, would be valuable in promoting more uniform sinter plant practice, and more intelligent diagnosis of various conditions resulting from its use in the blast furnace. Tests for size, chemical analysis, cold strength, hot strength, porosity, reducibility and microstructure are described briefly. In addition the authors give 53 references that adequately cover the entire field.

Almost any desired property of sinter can be measured by methods now in existence. The methods have been used mainly on a research laboratory scale. Adaptation, in most instances, will be necessary to make these tests suitable for plant work and also to accommodate local plant conditions. It would be highly desirable to have standardized test methods and procedures for plant-to-plant comparisons. One laboratory is working on this project. This

(Continued on p. 118)

*Abstract of paper, "Testing of Sinter", by E. G. Hill and R. E. Powers, presented before the General Meeting of American Iron and Steel Institute, May 23-24, 1951.



Charging end of the Stewart Bright Annealing Furnace showing blanks for P-K self-tapping screws coming off the Nichrome* conveyor belt made by Audubon Wire Cloth Corp. Furnace has been in continuous operation for more than 35,000 hours.

Discharge end of the furnace, at Parker-Kalon Corp., New York. Feeding is by an automatic electrically operated loader.

NICHROME* muffle passes 35,000-hour mark in non-stop performance at PARKER-KALON®

. . . and it's <u>still</u> going strong!

Does that make the Parker-Kalon Corp. happy? We should say so! Especially when they recall how, every year and a half, they used to mark time during a two-week shutdown. For that's how often they had to take down their annealing furnace to install a new muffle and belt. And the cost wasn't the worst of it . . . though it was plenty. What really hurt was the disruption of production schedules.

But that's all history now. Parker-Kalon anneals and normalizes its famous P-K self-tapping screws, thumb screws, wing nuts, and socket screws in a Sunbeam Stewart Bright Annealing Furnace equipped with a Nichrome* muffle and metal-woven belt. It operates at high annealing and normalizing temperatures, and handles a load that P-K's Production Manager, Harold Rosenberg, modestly describes as "substantially in excess of the 500-pounds-per-hour rated capacity."

The Nichrome* muffle and belt have been running at operating temperature for 35,000 hours, and they have never known a shutdown in four years. Yet neither shows any appreciable signs of wear or breakdown. And they are still going strong.

In similar ways, for over 35 years, we have been helping manufacturers meet their heat-treating requirements, to speed up operations, increase production, and cut costs. If you have such a problem, we invite you to consult with us. Although the present emergency's demands upon our resources are unprecedented, we shall gladly serve you to the limit of our ability.

SPECIAL PURPOSE ALLOYS SINCE 1899 · D H · TRADE MARK REG. U. S. PAT. OFF.

Nichrome* *is manufactured only by*

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T.M. Reg. U. S. Pat. Off.

Control Methods for Sinter

(Continued from p. 116)

paper reviews the present state of knowledge so that plants desiring it can set up their own tests for control purposes.

The establishment of control tests has two aspects: *(a)* Securing samples and *(b)* making tests. Sampling sinter correctly is very difficult. Local conditions govern the methods necessary and good judgment is the only general guide.

Size — A regular screen test at a given point in a plant should serve as an indication of strength. Not only average size but spread in sizes and content of fines is desirable. A method useful for comparisons is to plot the screen analysis on logarithmic-probability paper.

Chemical Analysis — One simple chemical analysis which sinter plants fail to make is for carbon in the fines from the screen test. This would be useful as a control method for completeness of burning or to tell whether fine sizes are the result of breakage or incomplete burning. Ferrous iron (FeO) is determined as a control test at some American plants. The FeO content together with total iron makes it possible to estimate the magnetite content. Swedish references continually emphasize the importance of minimum magnetite for greatest reducibility.

A rapid method for fayalite ($2FeO\,SiO_2$) is lacking and might be useful. Joseph determined it by reducing a sample with H_2 first at 600° C. and then at 1000° C. Magnetite is completely reduced at 600° C. while fayalite remains unaffected at the lower temperature.

Cold Strength — Several tests are cited, including coke drop test, crushing, impact crushing, and tumbling with minor variations in equipment.

Hot Strength — Some tests measure strength while the sample is under simulated blast furnace conditions, and some after the sample has been treated and cooled.

Porosity — The effect of porosity is based on the fundamentals of gas contact and penetration. Intergranular volume, total particle porosity, exterior particle porosity and interior particle porosity are defined and methods for their determination described.

Reducibility — Testing may be grouped under two headings: *(a)* Hydrogen, *(b)* carbon monoxide in bosh and blast furnace gases.

(Continued on p. 120)

protect your products from mold and bacteria

NOW... LATER!

Dowicide industrial germicides and fungicides are bringing manufacturers who use soluble-oil emulsions protection from bacterial contamination all along the line. Check this list of benefits *you* can derive from the use of Dowicide preservatives.

Dowicide products in soluble-oil emulsions:

1. Prevent emulsion breakdown with its accompanying oil separation and offensive odors.
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If Dowicide preservatives are not already protecting your soluble oils from mold and bacteria, phone, wire or write Dow today for additional information.

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Control Methods for Sinter

(Continued from p. 118)
Hydrogen was widely used because of its availability and its speed of reaction. On the other hand if, as contended by Hayes and McLeod, the rate of gaseous diffusion is one of the most important factors influencing reducibility, then tests with furnace gases might minimize the effect of one variable in the picture.

Magnetic Analysis — The Davis magnetic tube test is mentioned as a possibility for control testing to show the extent of oxidation of the sinter.

Microstructure — Results to date indicate that examination of the microstructure may be a valuable tool for research purposes. It has been shown that "incipient fusion" was not the correct mechanism of sinter formation because all the original ore materials were found to be altered.

At present, sintering plants are supplying sinter to the blast furnaces without specifications. This results from ignorance of what the most desirable properties are for the blast furnace. This impasse will always be present until measured properties of sinter are compared with blast furnace operation. Many ways can be seen to improve sinter and sintering, but until the properties of the product can be expressed numerically, there is no measure of the results of any changes made.

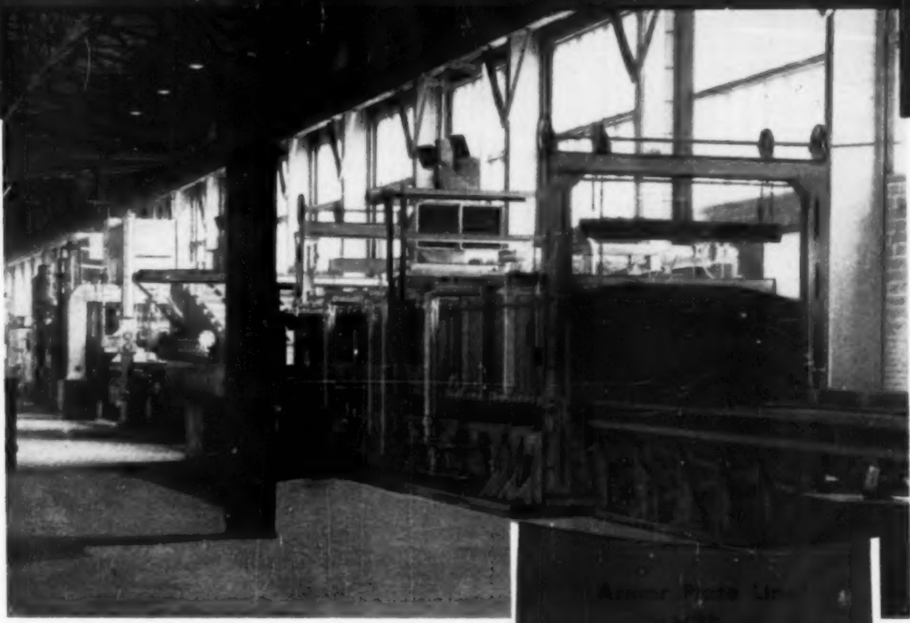
A. J. Hoch

Flame Hardening and Tempering of Steel*

Usual heat treatment methods, according to the authors, hinder continuous work flow in the production of quality and alloy steels. Such hindrance has been alleviated to some extent by the introduction of semi-automatic and automatic furnace installations. These installations are still complicated, however, so there has been a tendency to perform heat treatment without the use of furnaces. Examples of this approach are the heat treatment of stock by making use of the rolling and forging heat, and surface hardening by induction heating and heating with an oxy-fuel gas flame. *(Continued on p. 122)*

*Abstract of "Flame Hardening and Tempering of Steel", by Hans Bühler and Hans Wilhelm Grönegress, *Stahl und Eisen*, Vol. 71, March 29, 1951, p. 343-347.

DREVER CONTINUOUS ARMOR PLATE HEAT TREATING LINES



*Integrated High Capacity Heat Treating Lines featuring the Pressure Quench... produces **FLAT** high quality Plate*

Continuous, oil or gas fired Roller Hearth Furnaces for hardening and tempering both face hardened and homogeneous armor plate. Also Carburizing Furnaces and Car Type Furnaces for heat treating. Whatever your specific problem, consult DREVER.

DREVER CO.

700 E. VENANGO ST., PHILADELPHIA 34, PA.

Flame Hardening and Tempering of Steel

(Continued from p. 120)

Surface hardening involves the heating and quenching of only a thin layer of the piece. Methods were explored during the last war for annealing, hardening and tempering with oxy-illuminating gas flames, making use of the knowledge gained in the surface hardening field. By modification of the customary linear and rotational procedures for flame and induction hardening, pieces up to two to three inches in diameter or thickness can be heated with burners in as short a time as in surface hardening. The piece is then quenched in water to harden the entire cross section. A coupling arrangement of burners and sprays is often convenient. Flame tempering can be performed with the same modifications. The feature of such methods is that they allow complete heat treatments without use of furnaces.

Unalloyed steels with 0.27, 0.34, and 0.66% C, as well as alloyed steels with 0.20 to 0.49% C, 0.3 to 1.3% Si, 0.3 to 1.3% Mn, 0 to 1.8% Cr, 0 to 0.3% Mo, 0 to 2.7% Ni, and 0 to 0.2% V, have been hardened and tempered with flames. The authors report the experimental results of such heat treatments of these steels. Hardening through the entire cross section is possible with cross sections up to a maximum dimension of 3⅛ in. Working methods must be devised, which are suitable to the shape of the piece. The workpiece may be profitably preheated with burners, or burner systems, when large cross sections are involved. A comparison is given for the flame hardening, with and without preheating to 930° F., of plates of an alloyed steel (0.39% C, 1.79% Cr, 0.36% Ni, 0.10% V). Plates 2⅜ in. thick were hardened through the thickness when preheating was used, but were not hardened quite to the center of the thickness when preheating was not used. Preheating was absolutely necessary to obtain hardening through most of the plates that were 3⅛ in. thick. Plates of this thickness hardened only to a depth of 0.8 in. when preheating was not used. The temperature attained on the plate surface in the latter instance was estimated to be 1470° F., whereas the temperatures attained generally on plate surfaces were 1650 to 1830° F.

The strength properties estab-

(Continued on p. 124)

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

A-H5 ... air-hardening and easy to machine

Toolmakers rely on air-hardening tool steels to reduce the chances of cracking tools and dies during hardening. These steels are also preferred when only the minimum amount of distortion in heat-treatment can be tolerated. Air-hardening steels are deep-hardening, and have the high percentage of carbides that is so necessary for long wear.

From the toolmaker's standpoint, the principal objection to some air-hardening grades is their poorer machinability as compared with low-alloy tool steels. And that's why A-H5 is such a popular steel. It offers all the desirable properties of air-hardening steels, yet it can be annealed to 212 Brinell or less. It's a mighty easy steel to machine, especially when its all-around performance is considered.

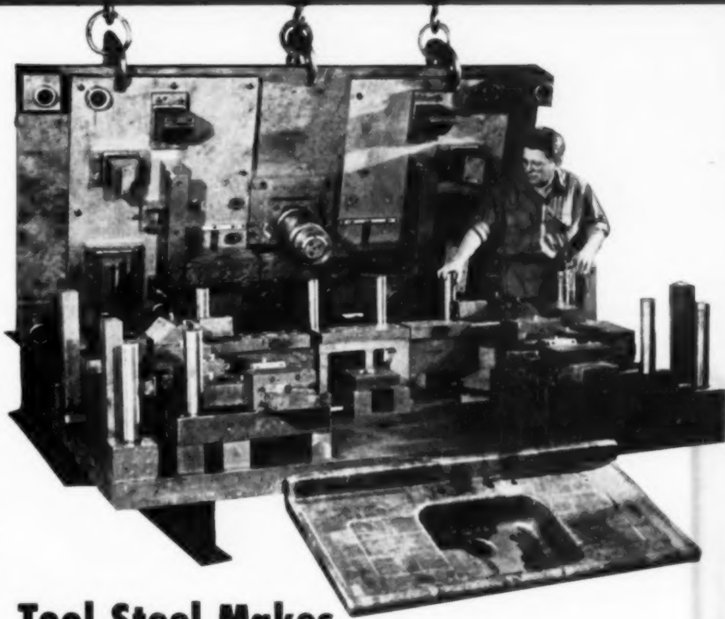
A-H5 is a general-purpose steel, suitable for nearly all tool and die jobs. Requiring a less drastic quench than standard oil-hardening grades, it also has greater wear-resistance, reduced distortion in heat-treatment, good shock properties. And its cost is on a par with the general-purpose, oil-hardening grades.

A-H5 is a steel worth looking into if you're looking for a safe, long-wearing tool-and-die grade that doesn't have to be pampered when it comes to machining and heat-treating.

Typical analysis:

C	Mn	Cr	Mo	V
1.00	0.60	5.25	1.00	0.25

Machining air-hardening tool steel causes no headaches in this shop because they're using A-H5. This user reports long wear and minimum distortion on a wide range of trimming and blanking dies.



Tool Steel Makes Kitchen Sinks, Too

Here's a man-sized die designed and built by A. F. & G. Tool & Die Co., Inc., Baltimore. Having wearing parts entirely of our BTR tool steel, this die is used to trim and pierce five different sizes of 14-gage steel kitchen sinks, one of which is shown in the foreground. Hardened to Rockwell C-56 to 58, this mammoth die will see service in a 250-ton press.

BTR, you know, is our general-purpose type of oil-hardening steel. It wears a long, long time and distorts very little in heat-treatment. Best of all, it's an economical steel that's easy to machine, easy to heat-treat.

Our Tool Steel Engineer Says:
Remove the entire surface of tool steel bars

It's important to remove the outside surface of tool-steel bars, even though portions of this surface do not serve as a working surface of the tool or die. Higher hardening stresses are set up in heat-treating a tool that has any decarburized surface.

Equal amounts of stock should be removed from *all* sides of a bar. This avoids warpage of the tool during heat-treatment. Sometimes a toolmaker will merely "skin" one surface of a flat bar and then, in order to arrive at the required thickness, remove all the remaining steel from the other surface. This is bad practice, not only because it invites warpage, but also because it is an incomplete removal of decarburization from the skinned side.

Bethlehem ULTRASONIC TESTED **Tool Steel**

A REGULAR SERVICE OF THE **COOPER ALLOY** FOUNDRY CO., HILLSIDE, N. J.

Technical Topics

ALLOY TYPE FA-20*

Norman S. Mott
Chief Chemist and Metallurgist

Although FA-20* was originally developed for use in hot sulphuric acid solutions, its high resistance in various media, as well as its superior physical properties, has increased its popularity to the point where it is presently being supplied by our foundry for valves, pump units, pipe fittings, and a variety of cast shapes used in the chemical, textile, paper, plastic and food industries.

FA-20 offers superior resistance, as compared with 18-8-SMO, in hot strong solutions of calcium or magnesium chlorides and aluminum sulphate; in dilute solutions of tin, zinc, iron or mercury chlorides at room and slightly elevated temperatures; and in cold dilute solutions of sodium or calcium hypochlorite. It is also superior in sulphur dioxide solutions or sprays, in dry chlorine gas at ordinary temperatures, wet hydrogen sulphide gas, boiling sodium or potassium hydroxide solutions of over 30% concentration, acid sludges up to 200° F., and in hot vinegar and salt solutions.

In sulphuric acid its use is required when the concentration is over 40% at room temperature, 10% at 175° F. or 0.75% at boiling; and it is satisfactory in all concentrations of this acid at temperatures up to 175° F., and up to 40% of concentration at boiling. It is recommended for boiling phosphoric acid when the concentration exceeds 10%, and for hydrofluoric acid of less than 10% or over 60% strength at room temperatures, although fair service may be had at all concentrations.

FA-20 is not recommended for use with wet chlorine gas or other wet halogens; chloroacetic acid; hot strong solutions of copper, iron or mercury chlorides; or with molten sodium or potassium hydroxides. It is satisfactory for service in nitric acid solutions, but for this use it offers no superiority over 18-8-type alloy and does not justify the additional cost.

Maximum properties at lowest cost are achieved when the alloy is cast to the following specifications:

Carbon	.07% Max
Chromium	20.00%
Nickel	29.00%
Copper	4.00%
Molybdenum	3.50%
Silicon	1.00%
Manganese	1.00%
Tensile Strength	75,000 psi
Yield Point	45,000 psi
Elongation 2"	40%
Reduction in Area	45%
Brinell	150

The nickel content offers good resistance to sulphuric acid corrosion and maintains the copper in alloy solution, minimizing the possibility of its becoming a contaminant in corrosion. Chromium provides resistance to nitric acid and other oxidizing media, and together with the nickel supplies the excellent mechanical properties of the alloy. Molybdenum and copper provide for increased sulphuric acid corrosion resistance and the molybdenum also increases passivity and reduces the tendency to pitting. The low percentage of carbon is essential for resistance to intergranular corrosion attack. Silicon and manganese are incidental to the production of the alloy, and in the amounts present provide little influence on mechanical or corrosion resisting properties.

*Produced under Durimet patents.

Flame Hardening and Tempering of Steel

(Continued from p. 122)

lished by the flame heat treatments are found to be equivalent to those produced by conventional furnace heat treatments, or those listed in specifications. The hardness decrease between the surface and the core is more abrupt in flame heat treated sections than when such pieces have been heat treated from the furnace. Micro and macrostructural investigations confirm the practical usefulness of the flame procedure.

Heat treatments were performed on steels of bar, tube and plate form, as well as girder profiles. The advantages of the methods described are the exceedingly short treatment times compared to the lengthy furnace procedures, the low installation cost, and the possibility of simple conversion of the installations to conform with change-overs in manufacture. An outstanding advantage is the ease of organization of the necessary installation into continuous work flow, a possibility which does not always exist with furnace installations. The examples cited show that generally the gas consumption is lower than in furnace treatment. However, the oxygen consumption may be regarded as a disadvantage, with the exception that wherever cheap oxygen is available this disadvantage may be counteracted by the advantages mentioned.

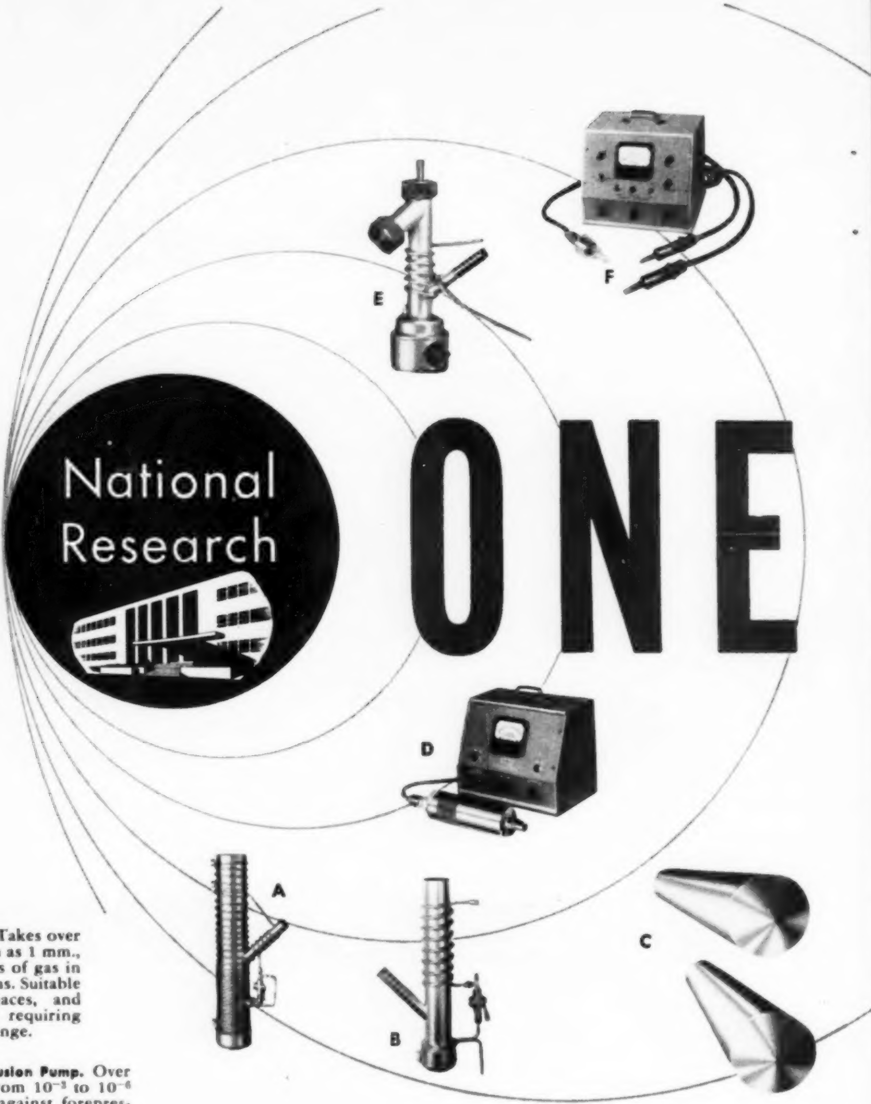
R. W. LINDSAY

Track Time and Soaking Pit Practice*

MUCH OF THE WORK being done to improve steel quality at the openhearth can be undone unless care is taken at the soaking pits. Mills that do not have hot deseamers must condition the slabs or billets by hand and this is slow and costly. With proper control over openhearth and soaking pit practice, the blooming mill product can be made suitable for direct charging into the reheating furnace of the finishing mills. Control of the soaking pits also contributes to fuel conservation and reduced costs.

(Continued on p. 128)

*Abstract of "Steel Quality as Affected by Track Time and Soaking Pit Practice", by A. F. Mohri, a paper presented before the General Meeting of American Iron and Steel Institute, New York, May 23 to 24, 1951.



(A) B-4 Booster Pump. Takes over at forepressures as high as 1 mm., handling large amounts of gas in range of 1 — 30 microns. Suitable for evaporators, furnaces, and other vacuum systems requiring high capacity in this range.

(B) H-2-P Purifying Diffusion Pump. Over 50 liters per second from 10^{-3} to 10^{-6} mm. range. Operates against forepressures as high as 0.300 mm. Blank-off 2×10^{-7} mm.

(C) Gas Free High Purity Metals. Copper, nickel, cobalt and iron. Special melts on request. Ingot weights up to 600 pounds.

(D) Alphatron® Vacuum Gauge. Accurate gauging from 10 mm. to 1 micron. A rugged metal ionization type instrument which can be adapted for recording, controlling, gas filling, and leak detection.

(E) B-1 Booster Pump. A small pump designed for rotary exhaust equipment used in miniature and subminiature tube production. Useful where a small pump is required to quickly obtain pressures in the region of one micron.

(F) Type 710 Thermocouple-Ionization Gauge Control. One instrument for scientific and industrial vacuum gauging. Incorporates two thermocouple gauges (1 — 1000 microns) and one ionization gauge (10^{-3} mm. to 10^{-8} mm. Hg. range) in one control. Automatic input regulation and protective circuit.

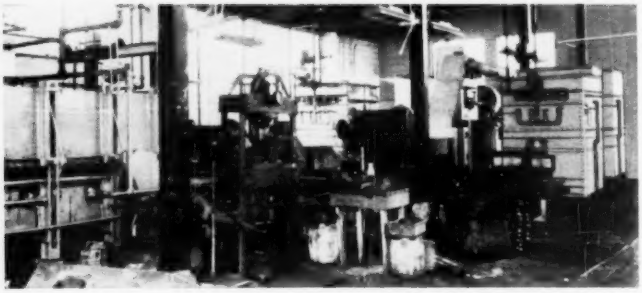
(G) Standard Vacuum Furnace. A versatile packaged unit to melt, pour, heat treat, degas, sinter, and anneal under high vacuum or controlled atmospheres. Temperatures up to 2000° C.

(H) Vacuum Seals. For introducing motion, power, or connecting gauges.

(I) High Vacuum Valves. Available in sizes ⅛" to 16". Low rate of leak.

(J) Vacuum Fusion Gas Analyzer. Analyzes metals and alloys, including titanium, for combined or dissolved oxygen, nitrogen, and hydrogen.

(K) Type 701 Thermocouple Gauge Control. A light, portable instrument for vacuum testing in range 1 — 1000 microns. Compact and rugged.



Track Time and Soaking Pit Practice

(Continued from p. 124)

This report is based on the operations of a plant that has a daily production of 3100 tons from two openhearth shops. There are eight regenerative pits and 14 bottom fired (Amco) recuperative pits operated with dry bottoms. The mixed fuel, with a heating value of 155 B.t.u., is six parts of blast furnace gas to one part of coke oven gas (not desulphurized). The Amco pits, on which most of this report is based, can accommodate sixteen 22 x 24-in. ingots (or 70 tons), and fewer of the larger. Approximately 4000 tons of ingots are heated daily, which means that considerable cold steel is picked up.

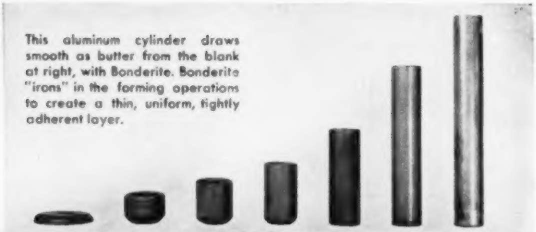
Pit temperatures are automatically controlled by thermocouples in the waste gas ports. Any one of four thermocouples located in each of the four corners may be connected to the controller which maintains a pre-set temperature. A thermocouple in the pit roof is connected to a pre-set temperature controller to protect the ingot tops from overheating.

Track time is defined as the interval from finish teeming to finish of soaking pit charging. The required soaking time is based on the interval from start of teeming to finish of soaking pit charging so as to include the effect of excessively long teeming time. Holding time varies with the composition and mold size and is specified from 15 min. to 3 hr. "Bridging-over" in hot top ingots and "cokey" centers in the deep etch test of billets have been attributed to insufficient holding time.

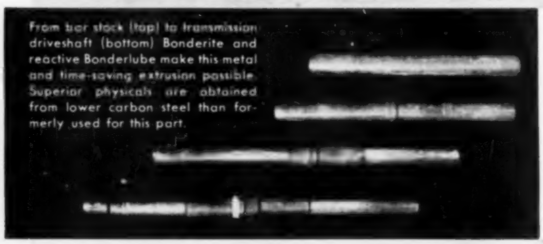
Alloy steel and high-carbon hot topped killed steel require a longer holding time than lower carbon steel because of the greater spread in temperature between teeming and solidification. A soaking pit schedule has been developed that specifies the charging, the desired heating rate, and minimum time in the pits. The minimum time in the pits varies from 2½ hr. for 22 x 24 ingots to 6 hr. for 26 x 53 ingots. The gas soak is based on two levels of track time: 45 min. for most grades having less than 6 hr. track time and up to 2 hr. for certain grades with over 6 hr. track time. The time soak is 15 min. more than track time if the track time is under 3 hr. 15 min., and 15 min. less than track time that is longer than 3 hr. 15 min.

Use of a second locomotive reduced track time from 3 hr. to 2.7

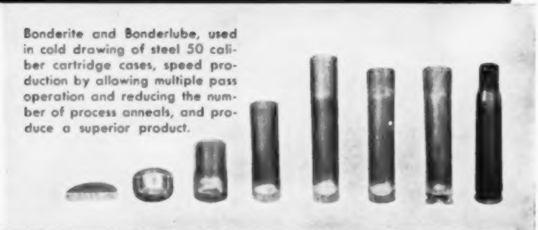
(Continued on p. 146)



This aluminum cylinder draws smooth as butter from the blank at right, with Bonderite. Bonderite "irons" in the forming operations to create a thin, uniform, tightly adherent layer.

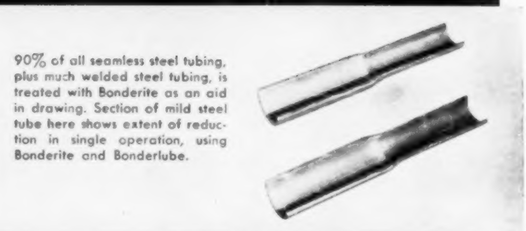


From bar stock (top) to transmission driveshaft (bottom) Bonderite and reactive Bonderlube make this metal and time-saving extrusion possible. Superior physicals are obtained from lower carbon steel than formerly used for this part.

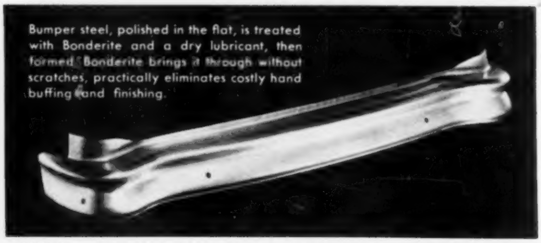


Bonderite and Bonderlube, used in cold drawing of steel 50 caliber cartridge cases, speed production by allowing multiple pass operation and reducing the number of process anneals, and produce a superior product.

The coined blank is treated with Bonderite and Bonderlube. One extrusion forms this close tolerance gear, which possesses excellent physical properties.



90% of all seamless steel tubing, plus much welded steel tubing, is treated with Bonderite as an aid in drawing. Section of mild steel tube here shows extent of reduction in single operation, using Bonderite and Bonderlube.



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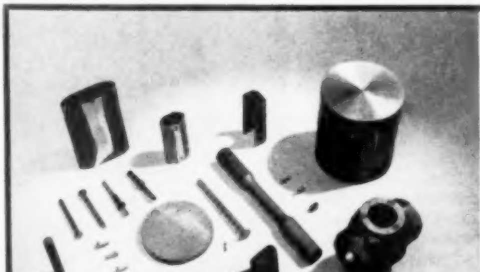

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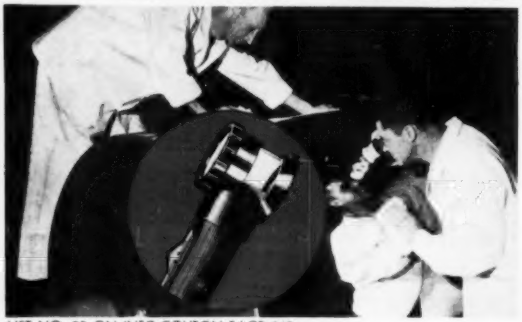

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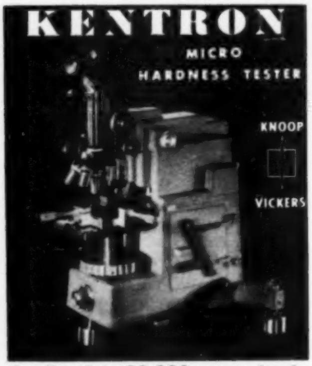

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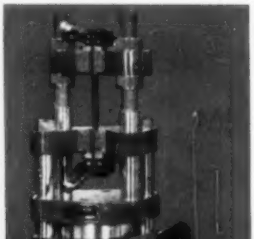

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Track Time and Soaking Pit Practice

(Begins on p. 124)

hr. and decreased the fuel consumption in the soaking pit from 963,000 B.t.u. per ton to 856,000 B.t.u. per ton. There was also a marked improvement in production rate at the blooming mill expressed in tons per hour. Track time affects the surface quality of many compositions. The effect is not marked with low-carbon rimmed, semikilled or killed steels which, if necessary, can be banked and subsequently charged into hot pits without much danger of poor surface or increase in conditioning costs. The low-carbon resulphurized steels are especially susceptible to surface defects if charged after long track time. Banking of such steel should be avoided as much as possible.

Carbon steels of about 0.20% C (C1020) and the high-carbon steels (C1080 or higher) are quite sensitive to track time. Straight chrome steels are less affected than alloy grades containing nickel or molybdenum, which are sensitive from the standpoint of surface quality. The A.I.S.I. composition 9260, a silicon-manganese steel, and the high-silicon steel sheets used for magnetic purposes are very critical to track time. Long track time, because of bunched heats or other operating difficulties, leads to rolling poorly soaked steel which is detrimental both internally and externally. Pipe, thermal shocks, and transverse cracks on charging into a hot pit are related to prolonged track time.

Short track time and rapid charging result in green steel. Semi-liquid steel may flow from the ingot and cause low yields and large blisters on the bloom. Such blisters may be 10 to 15 ft. long on the slab. An undersoaked ingot has a tendency to arc in the mill and cause cobbles. The difference in temperature from surface to center causes cracks and tears during rolling and increases conditioning costs.

Steel is considered well soaked if it meets three requirements of good heating. The exact times cited by Mr. Mohri apply to a 23 x 25-in. big-end-down rimmed ingot of C1015 and vary somewhat with size of ingot and grade of steel. The soak is controlled by setting the automatic gas controls at 2300° F. and adding 45 min. to the time at which the gas cuts back to where the heat input equals the radiation loss of the pit. This requirement

(Continued on p. 148)

Track Time and Soaking Pit Practice

(Begins on p. 124)

amounts to about 650 cu.ft. per min.

Several years ago the 10 to 1 blast furnace to coke oven gas ratio was changed to a 6 to 1 gas mixture. Detailed study was made of 80 consecutive charges heated in one typical Amco pit. Heats that had openhearth irregularities were not included in the study. The following results were secured:

1. The track time plus 15 min. for track times below 3 hr. 15 min. gives the same soak as track time minus 15 min. for track times of 3 hr. 15 min. to 6 hr. These results were used to amend the heating schedule that previously had called for track time plus 15 min. on all hot charged ingots.

2. A 6 to 1 mixture of blast furnace and coke oven gas gives a heating rate of 300 to 400° F. per hr. at low pit temperatures and of 100 to 200° F. per hr. when approaching soaking temperatures.

3. The spacing of the ingots is more closely related to the time required to reach soaking temperature than are the number and size of ingots.

4. Fuel consumption on cold steel was 2 million B.t.u. per ton with a pit efficiency of 37%.

5. The 6 to 1 gas mixture was appreciably more efficient than the 10 to 1 mixture.

6. Although the time in the pits is longer, the proper soaking interval is the same for hot or cold charged steel.

Soaking-pit heating conforming to specified minimum and maximum track time assists in improving the finished quality and in decreasing the necessity for scarfing or chipping. Differences in fuel would likely require revision of the details of the heating schedule.

F. G. NORRIS

Fracture of Metals*

THE PROCESS OF DEFORMATION of metals consists of three progressive actions: elastic and plastic deformations, and fracture. Although it is most important to make divisions between these three stages, so far it has often been impossible. It is well known that the transition

(Continued on p. 150)

*Abstract of "Process of Fracture of Plastic Metals", by Ya. B. Fridman and T. K. Zilova, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 697-700.

Fracture of Metals

(Begins on p. 148)

from the elastic to the elastic-plastic phase is extremely gradual, so that expedient divisions such as the 0.2% offset yield strength are employed.

No less difficult is the division between plastic deformation and fracture, that is, observing the beginning of fracture. If it is assumed that the first cracks can be about 10 Å in size, then most or all of the existing methods are insufficiently sensitive to observe such cracks, and the "first cracks" usually observed represent only a certain stage of development of the fracturing process.

The purpose of the present work is to show: *(a)* that with only the aid of macroscopic methods, it is possible to study the process of plastic fracture from its initial stages until final fracture occurs, and *(b)* that conclusions about the plastically deformed condition obtained from the study of completely fractured specimens may lead to incorrect results, because appreciable additional localized and general plastic deformation may occur in the development of the initially formed cracks. The deformed condition of the final, fractured specimen involves deformation before the beginning of fracture and additional localized and general deformation that occurs during the course of fracturing.

The localized plastic deformation of cylindrical specimens during static torsion was studied by means of a network of lines, 0.02 in. (0.5 mm.) apart, on the surface of the specimens. The process of loading was interrupted periodically to permit determination of the condition of deformation by study of the network of lines at a magnification of 27×. The procedure permitted the study of deformation before and after the appearance of cracks, as well as after fracture. Deformation was uniform before visible cracking occurred, but it changed to nonuniform localized deformation after the beginning of cracking in a manner that depended on the nature of the material. In all instances, however, the beginning of localized deformation was associated with the beginning of fracture.

Observation of the localized deformation at the base of the notch in a Charpy-type specimen subjected to static loading did not lead to such clear-cut results. In this case the localized deformation only increased in amount during the process of fracture. A. G. Guy

Coating Moisture and Weld Cracking*

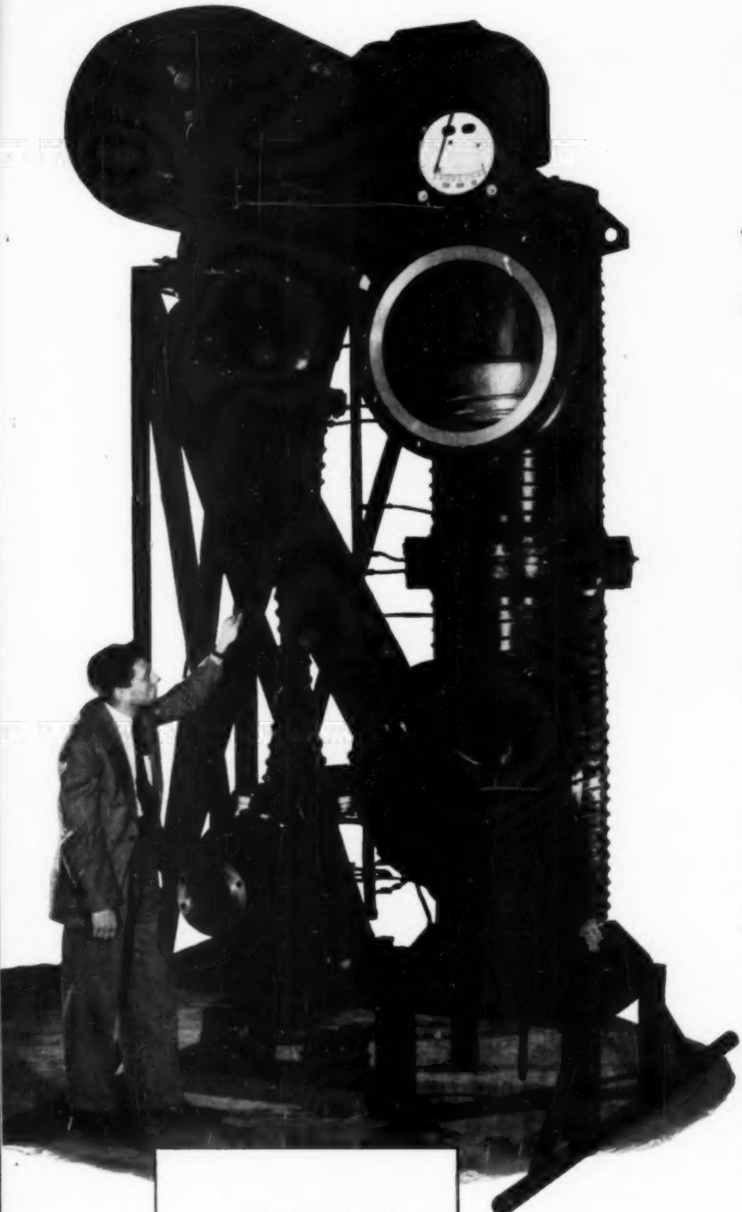
Welding hardenable alloy steels with ferritic-type electrodes presents complex problems because of the difficulty of "pinning down" the welding procedure factor or factors which are the primary cause of trouble in any particular instance. When this has been accomplished the problem of control of the application becomes the all-important consideration.

During World War II the Navy Bureau of Ships, in attempting to utilize the NRC-2A type of ferritic electrode (Mn-Mo with covering formulation similar to the austenitic type) as a substitute for the austenitic type in welding STS plate, obtained erratic and unpredictable results due to weld and bond-zone cracking. A study of this performance resulted in the discovery that this erratic behavior was caused by moisture in the covering of the electrode, both that absorbed from the atmosphere and that available from chemical compounds in the covering itself. As a result of this discovery, a program was initiated to develop an electrode having operating characteristics equal to those of the NRC-2A-type electrode but which would deposit weld metal of 85,000 to 95,000 psi. yield strength with 20% elongation in 2 in. and have an impact transition temperature of less than −40° F. No restrictions were placed on chemistry of the weld metal produced except that it was to be ferritic.

Many alloy combinations were investigated, most of which met the tensile property requirements but fell short in meeting the weldability requirements. These entailed deposition of satisfactory weld metal under a high degree of restraint at preheat and interpass temperatures of 0° F. Finally, a nickel-molybdenum-vanadium alloy combination was found which successfully met the weldability requirements but only one electrode manufacturer's coating formulation would do it. This necessitated a study of coating formulation and electrode processing with the result that moisture content of the covering was found to be of major influence in electrode performance. Baking at high

(Continued on p. 154)

*Abstract of "Nickel-Molybdenum-Vanadium Alloy Steel Shielded Arc Welding Electrodes (Low Hydrogen Type)", by E. H. Franks, C. T. Gayley and W. H. Wooding, *Journal* of American Society of Naval Engineers, Vol. 62, August 1950.



Coating Moisture and Weld Cracking

(Continued from p. 152)

temperature to reduce moisture content was found to be beneficial.

Following this development another grade of electrode was developed to produce weld metal of 110,000 psi. minimum yield strength. The weldability requirements for this electrode were that it be suitable for depositing satisfactory weld metal under conditions of very high restraint at preheat and interpass temperatures of 70 to 100° F. However, the impact properties of the weld metal were not as good as anticipated.

Experience with the use of these electrodes at various shipyards indicated a general acceptance which was encouraging. In some instances a preference was indicated for this type of electrode over the 25-20 austenitic electrode. The covering is essentially of a lime-titania type with an absence of organic or cellulosic materials.

A comparison of the operating characteristics of this ferritic-type electrode with those of the austenitic-type electrode shows that at the same welding current level the ferritic electrode has a lower burn-off rate than the austenitic electrode. However, as the current is increased, the ferritic electrode improves in its arc characteristics, whereas the austenitic electrode deteriorates. Deposition efficiency of both electrode types is about the same at the lower current values, but the ferritic electrode shows higher efficiency and considerably greater depth of penetration at optimum welding current (150 amp. for 5/32-in. electrode; 225 amp. for 3/16-in. electrode). Optimum for 3/16-in. austenitic electrode is about 175 amp.

An observed characteristic of this ferritic electrode is the formation of a "crucible" or crater at the end of the electrode which suggests that the core wire melts off ahead of the covering. The depth of this crucible appears to be a direct function of welding current. This suggests an explanation for the observation that the visible mechanical arc length decreases with increasing welding current at constant arc voltage.

The effect of moisture in the electrode covering on weld cracking was investigated using the Navy Circular Patch Test. As a result of this work a maximum moisture content of the covering of 0.2% by

(Continued on p. 156)

Coating Moisture and Weld Cracking

(Continued from p. 154)
weight was established for satisfactory operation of the 110,000-psi. yield strength electrode. Since this type of electrode covering will absorb moisture when exposed to humid atmosphere, it was established by a series of tests that baking for an hour or more at 900° F. will reduce the moisture content to within the maximum limit of 0.2%. However, a higher baking temperature is not recommended because of the danger of oxidizing the ferro-alloys in the covering.

A study of the effect of joint geometry on weld metal soundness indicated that the root opening, with a 60° Double-V groove, should be not less than $\frac{3}{32}$ in. nor greater than the electrode diameter (core wire diameter). This suggests that good fit-up is essential if satisfactory butt welds are to be obtained with this Ni–Mo–V-type low hydrogen ferritic electrode. Where fillet welds are involved it is important that the plate surfaces be cleaned prior to welding to avoid porosity in the welds.

It was determined that in depositing the root layers of butt joints it is essential that layer contour have some degree of concavity and wash up on the sides of the scarf to avoid re-entrant angles at the junction with the scarf face. These reentrant angles are conducive to formation of heat-affected zone cracks.

W. L. Warner

Spheroidal Graphite in Cast Iron*

The method of quenching alloys in the course of their solidification was used to study the crystallization of cast iron with spheroidal graphite. The cast iron contained 3.5 to 3.7% carbon and 2.2 to 2.5% silicon and was modified using Elektron metal by the method described by Mil'man in 1949.

Cylindrical specimens 20 mm. (0.79 in.) in diameter were slowly cooled in a furnace or in a sand mold until they were partially solidified. Water quenching was then used to convert the remaining liquid to ledeburite, which could be identified under the microscope.

*"Crystallization of Cast Iron With Spheroidal Graphite", by K. P. Bunin and G. I. Ivantsov, *Doklady Akademii Nauk SSSR*, Vol. 72, 1950, p. 1051-1053.

Study of such specimens showed that the graphite grows, basically, in the eutectic temperature interval. At higher temperatures only a negligible portion of the graphite crystallizes. The authors state there is a possibility that nonmetallic inclusions may have a certain amount of influence in the nucleation of graphite.

The growth of flake graphite in the melt is difficult, and even in the early stages the graphite particles acquire a spherical form. This behavior is dependent on the presence of magnesium in the melt, since on decreasing the magnesium concentration there is a tendency toward the growth of flake graphite.

In the beginning of the eutectic interval, the graphite particles are overgrown with a continuous coating of austenite. In the process of eutectic transformation the graphite particles grow in the austenite without having contact with the liquid, because as they grow the austenite coating becomes thicker. Eutectic decomposition ends with the complete transformation of the liquid into a mixture of austenite and spheroidal graphite. In the process of flake graphite formation, on the other hand, both graphite and austenite are in contact with the liquid.

Cause of the diffusion of carbon through the austenite from the liquid to the graphite was explained as follows: If the eutectic decomposition of the liquid proceeds at a temperature below the eutectic range, then the layer of austenite separating the graphite and liquid will be nonuniform chemically. The austenite in contact with the liquid will have a composition corresponding to metastable equilibrium between austenite and liquid, while the austenite in contact with the graphite will have the lower equilibrium carbon content.

However, the form of the graphite particles and their rate of growth are determined not by the process of carbon diffusion, but by the process of moving away of the iron atoms from the crystallization front of the graphite, thus increasing the hollow in the austenite for holding the graphite. The latter process, which depends on the self-diffusion of iron, is slower by a factor of 10^4 than the diffusion of carbon. The vacancies involved in the "hole" process of diffusion are pictured as flowing from the surface of austenite solidification to the crystallization front of the graphite.

(Continued on p. 158)

Spheroidal Graphite in Cast Iron

(Continued from p. 157)

Under these conditions the form of the graphite particle is not determined by the structure of graphite but by the shape of the hole created by self-diffusion in the austenite. An existing hole would grow into a sphere and thus lead to a spherical graphite particle.

Thus, to successfully obtain spheroidal graphite particles it is not sufficient to prevent the formation of flakes of graphite in the crystallization of the liquid, a result produced by magnesium, but it also is necessary to free the growth of the graphite particles within the austenite. This can be done by accelerating the self-diffusion of the iron atoms. One means of doing this is by increasing the silicon.

According to the authors, an incorrect picture of the influence of silicon on graphitization has existed until now. This effect occurs not only because of the influence of silicon on carbide stability and carbon diffusion velocity, but often because of its influence on self-diffusion of the iron atoms in austenite through a decrease in the activation energy. Experimental verification of this effect has been obtained in the author's laboratory. If there is insufficient silicon in the cast iron, the growth of the graphite within the austenite stops and white iron is obtained. In this case it is possible to convert white iron to gray iron with spheroidal graphite by slow cooling in the solid state. The mechanism of such graphitization will not differ essentially from that described above, the source of carbon being carbide rather than liquid. A. G. GUY

Oxidation in the Presence of Molybdenum Oxide*

THE AUTHORS attribute the rapid oxidation of metals and alloys in the presence of MoO_3 to the formation of liquid oxide phases in contact with the metal. Tests were conducted on copper, 8% aluminum-bronze, iron, nickel, 25% chromium steel, 19-9SCb, silver, and a 4% aluminum-silver alloy. The

(Continued on p. 160)

*Abstract of "Rapid Oxidation of Metals and Alloys in the Presence of MoO_3", by G. W. Rathenau and J. L. Meijering, *Metallurgia*, Vol. 42, 1950, p. 167-172.

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Oxidation in the Presence of Molybdenum Oxide

(Continued from p. 158)

specimens were heated at various temperatures in contact with MoO_3 and the extent of the oxidation was measured by loss in tensile strength of the wires. Metallographic and X-ray studies were also made.

Oxides of the metals were heated with molybdenum oxide to determine eutectic arrests. Arrests at 735 and 500° C. were found with CuO and Cu_2O, respectively. The addition of Al_2O_3 to the latter mixture decreased the arrest temperature 5° C. Oxidation of copper in contact with MoO_3 increased rapidly at around 530° C. while that of the 8% aluminum-bronze at about 470° C.

A MoO_3-MoO_2 eutectic was observed at 778° C. Additions of Cr_2O_3 lowered it to 772° C. and NiO additions to 764° C. MoO_3 with 8% MoO_2, 6% FeO and 6% Cr_2O_3 showed an arrest at 705° C., which is the lowest arrest temperature observed for these oxides. Oxidation of nickel, 25% chromium steel and 19-9SCb increased rapidly at about 775, 770 and 740° C., respectively. The 19-9 wires oxidized both with and without MoO_3 and showed intercrystalline penetration.

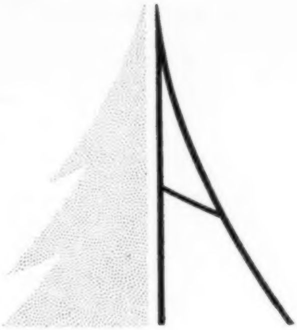
Silver does not oxidize above 180° C. because of the high vapor pressure of its oxide. Oxidation in the presence of MoO_3 was observed by the authors. The foreign oxide stabilizes the Ag_2O and oxidation proceeds.

The authors state that liquid oxides cause abnormal oxidation because a liquid film forms at grain boundaries of the oxide and at the interface between the metal and oxide. Diffusion and convection in a liquid are, of course, very rapid, allowing speedy oxidation.

COMMENTS BY THE REVIEWER

The reviewer believes that Rathenau and Meijering are taking too narrow a view of the problem of rapid oxidation. Their paper indicates that the rapid oxidation is due entirely to a slagging action. For example, they express surprise that Leslie and Fontana's paper (*Transactions*, American Society for Metals, Vol. 41, 1949, p. 1213) and the discussion do not mention the presence of liquid oxide formation. The Leslie and Fontana investigation did not observe liquid oxides and their mechanism does

(Continued on p. 162)



Oxidation in the Presence of Molybdenum Oxide

(Continued from p. 160)

not require the formation of liquids.

The slagging effects of molten oxides have been known for many years. Rathenau and Meijering merely show that MoO_3 can act as a component in one of these slags or oxide mixtures. I believe there are two distinct mechanisms that could contribute to the rapid oxidation in the presence of MoO_3, namely: *(a)* attack in the absence of molten slag that proceeds according to the mechanism proposed by Leslie and Fontana and *(b)* the localized attack involving molten slag.

The slag theory does not present a complete picture because it fails to explain *(1)* the absence of attack in a moving or circulating air atmosphere and *(2)* the concentration of the rapid oxidation at points of concentration of MoO_3 vapor. Further support for item *(2)* was presented by Fontana in *Industrial and Engineering Chemistry*, Vol. 42, 1950, p. 65A-66A that reported on a study of vanadium oxide. Specimens of steel were semi-immersed at a 45° angle in molten vanadium oxide. The greatest attack occurred at the liquid line on the underneath portion of the specimen or the "pocket" wherein vanadium oxide vapors could collect and were stagnant (similar to the results observed with MoO_3). Incidentally, no differences in attack were observed between freshly abraded specimens and those with previously formed iron oxide scale.

Rathenau and Meijering infer that their work and the Leslie and Fontana investigation were conducted at the same time. This is probably not the case because most of the Leslie and Fontana work was done in 1947 and presented during the 1948 National Metal Congress.

M. G. FONTANA

Strains and Stresses*

THE STRESS AND STRAIN conditions during elastic deformation of notched metal specimens have been studied in detail. However, in most instances plastic and elastic deformation occur prior to fracture, even in the presence of a sharp

(Continued on p. 164)

*Abstract of "Concentration of Strains and Stresses at Large Plastic Strains", by Ya. B. Fridman and T. K. Zilova, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 1185-1188.

Strains and Stresses

(Continued from p. 162)

notch. The plastic deformation may be highly localized and may not be visible on macroscopic examination of the fracture.

Brittleness in which microscopic (localized) plastic deformation occurs is associated with either shear or tensile fractures and can be observed in ductile metals under conditions of irregular deformation or in the presence of notches.

The concentration of deformation was studied on plane and cylindrical specimens using the method of a network of surface lines. The stress concentration in the elastic range was known for these specimens. The load was gradually increased until fracture occurred, and, at each step in loading, the network of lines was examined at 27×.

From the local shift of the network, the coefficient of concentration of deformation was calculated as the ratio of the maximum shift to the average shift. Then, from the experimental curve of deformation in torsion, the equation $t_{max} = f(g_{max})$ was derived for specimens of copper and duralumin subjected to tangential stresses. From the curves of shift and stress it was evident that even in completely plastic metals, such as copper, and in the presence of extensive plastic deformation nearly to the point of fracture, concentrations of stress and of deformation remained. Nonuniform deformation in the notched cross section was evened out only after completion of fracture.

An increase in local deformation near a stress concentrator decreased local deformation in the region immediately adjacent. The "relieved" or less deformed zone, known in notched specimens as the elastic region, is retained after transition to large plastic deformations. Relieving grooves may be used in plastic as well as in brittle materials in some applications.

In a deeply notched cylindrical specimen pulled in tension it was found that the local plasticity (measured on a base network of 0.5 mm.) was about four times as large as the average deformation determined by the reduction in area of the notched cross section in both aluminum and an annealed steel. Therefore, the usual method of measuring plastic strain does not give a true measure of the localized deformation.

A. G. Guy

GLOBAR elements used in HAYES Furnace to assure

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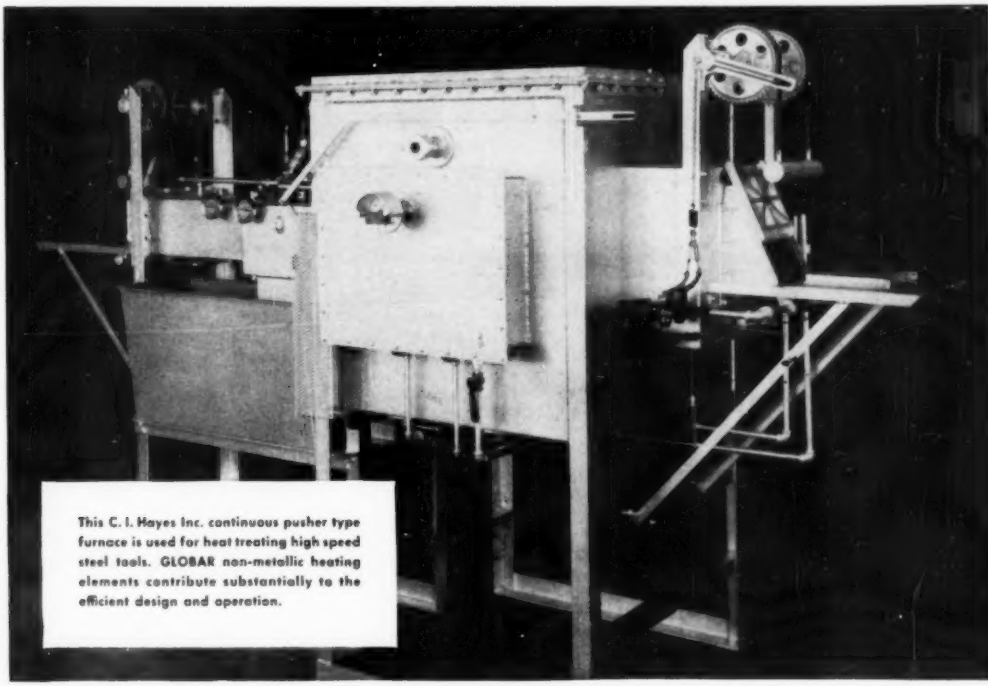

This C. I. Hayes Inc. continuous pusher type furnace is used for heat treating high speed steel tools. GLOBAR non-metallic heating elements contribute substantially to the efficient design and operation.

GLOBAR silicon carbide heating elements provide an ample margin of safety at the normal operating temperature of this heat treating furnace. Peaks in production are handled without danger of costly breakdowns. Dependable performance and low maintenance cost on regular production schedules are assured. Simplicity of furnace design and construction provide fast, simple element installation ... even while the furnace is at temperature. Heating is clean, silent and safe.

For more detailed information on the installation and operation of GLOBAR non-metallic heating elements, write Dept. MP-121, The Carborundum Company, GLOBAR Division, Niagara Falls, New York.

GLOBAR Heating Elements

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Ceramic Coatings

(Continued from p. 91)

which excludes the product causing corrosion. However, 17-14 Cu Mo formed a loose scale which did not prevent attack by corrosive media.

N-155 — The header made from N-155, after 1098 hr., shows heavy grain boundary precipitation and agglomeration of secondary phases within the grains. The hot interior surface is shown in Fig. 7 (p. 91); a white decarburized layer is also evident. The heavy precipitation reduces the ductility, and a 35 to 40° bend results in a brittle fracture. After 1623 hr. in test, the N-155 header was badly pitted from high-velocity blow-by of exhaust.

CONCLUSIONS

The tests described above indicate that presence of the ceramic coating on the 19-9DL headers successfully protected them from deterioration from oxidation, carbon absorption and corrosion attack for the test periods and under operating temperatures up to 1800° F. Additional and continued testing is being conducted by the Ryan Development Laboratories, but it is now becoming definitely established that ceramic coatings are beneficial in extending the life of the heat and corrosion resistant alloys where oxidation and corrosion are major problems.

While investigators are not as yet in agreement as to the effect of lead compounds in high-octane gasoline on the life of metal subject to their hot combustion products, the rapid deterioration of the austenitic grades of stainless steel conducting the products of leaded fuels is due to high rates of carbon absorption with resulting surface embrittlement and loss of corrosion resistance. Enameling prevents this carbon absorption and provides a major improvement in life of these structures. The ceramic coatings are persistently adherent to the metal's surface, even though they change in appearance and are almost impossible to detect except by spectrographic analysis.

Tests in Lead Bromide Vapors

TECHNICAL NOTE 2380, N.A.C.A., cited in the footnote on p. 87, describes tests which parallel Mr. Hubbell's, and warrant brief description. The authors, Moore and

(Continued on p. 168)

Tests in Lead Bromide Vapors

(Continued from p. 166)

Mason, covered ½ x 1½-in. samples of 18-g. sheets with Bureau of Standards' ceramic coatings A-417, A-19 and A-520. Metals were 19-9 DL, Inconel (78 Ni, 14 Cr, 7 Fe), Haynes Stellite 21 (62 Co, 28 Cr, 5.5 Mo, 2.5 Ni, 1 Fe, 0.2 C), S-816 (44 Co, 20 Cr, 20 Ni, 4 Mo, 4 W, 4 Cb, 3 Fe, 0.4 C), and A.I.S.I. stainless Type 347 (18 Cr, 10 Ni, 0.8 Cb, 0.08 C). Specimens were dip coated in the enamel, fired, and suspended in a small crucible furnace, electrically heated. The atmosphere contained $PbBr_2$ gas in considerably higher concentration than encountered in air engine exhausts. Temperatures of tests were 1350, 1500 and 1650° F.

Each test consisted of six successive heatings of 1 hr. each; at hourly intervals the samples were removed, a portion sandblasted free from corrosion product and its thickness measured. Chemical attack was assumed to be related to the decrease in thickness. Check specimens were run bare (sandblasted) and also after pre-oxidation at test temperature.

The lead is added to the gasoline as tetraethyl lead and at the same time ethylene dibromide is introduced. The purpose of the ethylene dibromide is to act as a scavenging agent, that is, to convert the PbO, which would otherwise be formed during combustion, into $PbBr_2$, which has a considerably higher vapor pressure than lead oxide and is therefore more easily passed through the exhaust system as a vapor.

Confining this summary to some results of tests at 1500° F. for 6 hr., it was noted that the bare samples in all instances corroded at the highest rate. Pre-oxidation always cut this corrosion somewhat; reductions were 20 to 30% for Inconel, Haynes Stellite 21, and 19-9 DL; from 5 to 10% for stainless Type 347 and S-816. When hour-by-hour figures are examined, it appears that the oxide scale has far better protective power during the first one or two hours of exposure, but once this protective barrier is penetrated, the attack progresses as fast as though no oxide scale had been present.

Ceramic coating was highly protective in all tests. Results for the various alloys follow, where the first figure is the average loss

(Continued on p. 174)

To Be Weighed With the Joys of Christmas

THE continued revelation of our human immaturity in diplomatic relations with our enemies, and particularly our hamstringing of our military forces in the functional conquest of victory, pose most distressing thoughts for the New Year. Whatever the doubletalk deal with Communism, *it still stinks*.

Viewing moral degeneration at all levels of a geometrically expanding bureaucracy, we ponder on the parasitic load which we are passing on to the next generation.

Another year—another **CHRISTMAS**—has rolled by with increasing inflation. Inflation is another name for the depreciation and dissipation of sound and true values in savings, insurance, and earning power.

Changes in the pattern of American tradition of Yankee ingenuity are not satisfying. We who have led in high-temperature mechanism are getting our jet engine designs from Britain—complete with designed-in production retardations—and our "new" aircraft forging techniques from Germany, with an unexplained five-year lag.

That we currently have no integrated plan for parallel casting process development, to employ more effectively our second largest metals industry, reveals areas of vacuum where we might expect *substance*.

The present plight of the British Empire has been described as a pseudo-social "homogenation", which, failing in redistributing the "fat", oxidized most and precipitated the remainder to the bottom. The British, however, did stop short of throwing away the stud book.

A solid core of British *Character-Exemplified-in-Action*, the functionally trained professional engineering and management group, embracing all engineering arts and sciences, has *not succumbed* to economic or political stagnation. They are *delivering the goods*, coming up with major contributions to the scientific and mechanical implementation of modern warfare.

Such contributions from all sources offer our major hope of consuming the cannon fodder of Asiatic breeding grounds in *the narrowing time and space* that separates them from the conquest of a fat, indolent, and degenerating sphere of "Freedom".

Consider the probability that our politicians, bureaucrats, and assorted saboteurs ("red herrings") cannot louse us up beyond the expanding capacity of our engineers and productive industry to defend us. Given unequalled tools, our *true strength*, our children's future, will *depend upon our return to IDEALS, ETHICS, and MORALITY* traditional in **AMERICAN CHARACTER**. This nation, led by its politicians, weighted by its parasites, and undermined by the leprosy of Communism, *has strayed too far!*

Our materialism can spell *Destruction*, or the *Triumph of Freedom*, in proportion to its *increment of CHARACTER at all levels*—individual, family, community, and national.

Some measure of human life is *the unavoidable price of survival*. To be *worthy* of freedom and future, bought with the lives of American boys, imposes a *sacred obligation on each of us*. Our rededication is imperative. *We*, the works of our forefathers, and *all that we stand for*, face trial for *survival*. *Any compromise short of VICTORY*, with those whose announced purpose is our destruction, will lead to *CERTAIN DISASTER*.

H. H. Harris

RELATIVE TO CASTINGS

It is difficult to convince many engineers that castings need not necessarily follow the process-inherent irregularities of structure and fatigue life that have survived through the centuries. Engineers who are familiar with the accelerated stresses of loaded alloy castings in myriad functional configurations under cyclic heating-and-quenching operations are generally aware of the increasingly superior performance of General Alloys castings.

In 1928, we demonstrated that fatigue life is inversely proportional to grain size, and subsequently that the integration of chemistry and structure (by steadily advancing casting process) produces castings of high integrity and superior function.

The extent of General Alloys' research in process-function-life relationship is unique in the entire casting industry—to which much of it is broadly applicable.

The General Alloys Exhibit, for 33 consecutive years at the Main Entrance at National Metal Shows, is receiving increasing recognition for its educational contribution to casting technology and to those who would design and use heat and corrosion-resistant castings with maximum understanding and utilization of advanced casting process.

GENERAL ALLOYS COMPANY

BOSTON, MASS.

"OLDEST AND LARGEST EXCLUSIVE MFRS. OF HEAT & CORROSION-RESISTANT ALLOYS"

Tests in Lead Bromide Vapors

(Begins on p. 166)

in thickness in mils of the unprotected alloy and the second figure the corresponding loss of the piece protected by A-417 coating.

19-9DL: 10.1 → 1.1
Type 347: 9.8 → 0.2
S-816: 6.6 → 0.5
Inconel: 6.2 → 0.3
Stellite 21: 3.5 → 1.0

There appears to be no significant difference among the three ceramic coatings in these tests, except that A-417 seemed to have the best adherence.

Uncoated specimens of all alloys scaled freely in these tests. In most instances, corrosion of the protected alloys was of a pitting type, and a ball-probe micrometer was used to penetrate the pits and measure the remaining thickness of metal.

Several of the tests at 1650° F. showed less corrosion than the corresponding experiments at 1500° F. While such results "are not unusual in corrosion studies of alloys", the authors point out that (in their equipment) the concentration of $PbBr_2$ in the furnace atmosphere at 1650° F. may have been considerably less (on the average) than in the runs at 1500° F.

Spectrochemical analysis of the scale shows such small amounts of lead that the authors assume the $PbBr_2$ has penetrated into the alloy structure — possibly as elemental lead. As to the mechanism of attack, previous work by the authors indicates that $PbBr_2$ destroys the tight, impervious scale that normally forms and inhibits further oxidation.

The authors' main conclusion is that "the ceramic coatings appeared to be inert to the $PbBr_2$ fumes and thus successfully inhibited the corrosion of all the alloys investigated for the full test period of 6 hr."

Chromium-Frit Coatings for TiC Ceramals*

Earlier work conducted by the N.A.C.A. indicated that an 80% TiC – 20% Co sintered composition (manufactured by Kennametal, Inc.) appeared to be suitable for jet engine turbine-blade applications, although oxidation resistance was insufficient for long-term operation. Subsequently, N.A.C.A.-sponsored work at the National Bureau of Standards revealed that a ceramic metal coating containing chromium metal particles suspended in a glassy matrix was effective for long periods in decreasing oxidation of this ceramal at 1800° F. This summary describes further work by Moore, Benner and Harrison, National Bureau of Standards, on the effect of glassy phase content on the oxidation resistance of the carbide material at various temperatures, its relation to transverse rupture strength and thermal shock resistance.

Four coatings were prepared with the chromium to glassy phase ratios of 100:0, 90:10, 80:20 and 70:30. The glass, made as a frit, contained 38% SiO_2, 6.5% B_2O_3, 44% BaO, 4% CaO, 5% ZnO, 2.5% BeO. It is noticeably free from alkali oxides which might attack the titanium carbide during long-time heating periods.

The coatings were applied by dipping on ¾ x 2½ in. specimens 0.132 in. thick. The thickness of fired coatings was seldom less than 3 mils and occasionally above 10 mils. Fusion was achieved by heating at 2200° F. in hydrogen for 10 min.

Coated and uncoated specimens were oxidized at temperatures of 1650, 1800, 2000, and 2200° F. for 400, 200, 100 and 50 hr. respectively in various increments of time. Oxidation was measured by differences in specimen thickness before and after heating. The final reading was obtained on the carbide specimen after the chromium-frit coating and oxide interface had been removed by sandblasting. Results indicated that low glass content gave best oxidation resistance at 2200° F., but high glass content gave best oxidation resistance at 2000, 1800 and 1650° F.

Transverse breaking strength was measured on oxidized specimens prior to sandblasting. The coating containing the least amount of frit (10%) had an average strength that was only 11.1% greater than the weakest specimens which contained 30% frit.

The authors conclude that the chromium-frit coating merits consideration for inhibiting the oxidation of sintered titanium carbide in high-temperature service.

*Abstract of "Studies of High-Temperature Protection of a Titanium Carbide Ceramal by Chromium-Type Ceramic-Metal Coatings", by Dwight G. Moore, Stanley G. Benner, and William N. Harrison, Technical Note 2386, June 1951, National Advisory Committee for Aeronautics.

These ceramic-coated exhaust parts for Ryan Aeronautical Company are entering the furnace on Inconel points for firing at 1850°F. at plant of the California Metal Enameling Co., Los Angeles, Calif.

Ceramic protected aircraft parts fired at 1850°F. on Inconel burning tools

It takes temperatures up to 1850 F. to fire the protective ceramic coatings on aircraft exhaust parts.

Naturally the burning tools used in such an operation have to be tough. Time after time they are sent into the furnace to take a high temperature beating that few materials can hold up under . . . for any length of time.

But the tools are no problem to California Metal Enameling Company who fire the parts for Ryan Aeronautical Company in Los Angeles.

That's because they use Inconel!

They find Inconel extremely resistant to corrosion and oxidation at temperatures up to 2200°F. They also find that Inconel's high hot strength permits lighter weight fixtures with correspondingly lower fuel costs.

And as a result of their findings, practically all the burning tools and hooks in their plant are made of Inconel. *And they have worked perfectly since the first firing!*

Right now, Inconel is hard to get because so much is being diverted to defense. But if you have a high-temperature metal problem in your operation, INCO's High Temperature Engineers will gladly help you search out a solution. Write today and ask them to send you a High Temperature Work Sheet on which you can easily outline your problem.

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for long life at high temperatures

How Accurate Is the Impact Test?

(Continued from p. 71)

were much less sensitive to hardness level changes than the V-notch tests. This is a matter which requires consideration when specifications are being promulgated.

6. The grave question of the reliability of impact tests is inescapable. If impact tests are specified, what consideration should be given to limits of acceptance? Probably the first inclination would be to increase the severity of acceptance limits as insurance. Would this lead to unnecessary rejections which eventually must be reflected economically? Acceptance limits for some parts are now impractically close to the highest values obtainable with the best known practice. With few exceptions, this presents a very unsatisfactory condition for all concerned.

While not referred to in this report, the temperature at which the impact test is conducted is very important. The testing temperature may be in or close to the transition zone of the material and, if so, small temperature variations may disproportionately influence the results. Testing at other than room temperature introduces additional sources of error.

It must be determined what the test is capable of revealing about the serviceability of a part or about other qualities of the material from which it is made before impact tests are specified. If impact tests are then specified, those responsible for selecting the values should be aware of the test's limitations.

New Uses of Gases in Metallurgy*

The author discusses the theory of absorption of gases in metals, and mentions hydrogen and nitrogen as the worst offenders. Iron rust contains a large amount of water; Bardenheuer is quoted for the statement that 1% of rust in a 10-ton bath of steel introduces as much as 900 cu.ft. of hydrogen (measured under standard conditions). Reference is made to the need of enlisting oxygen in the fight against hydrogen, but that deoxidation removes this protection and the hydrogen starts to pour into the molten metal from all available sources, until the metal has finally solidified in the mold. It becomes desirable, therefore, to displace this hydrogen immediately before pouring. The work of Sims, Zapffe, and Eastwood are referred to in connection with the hydrogen problem.

An excess of nitrogen in steel induces blowholes while in nonferrous metals nitrogen is quite inert. The method of "flushing" is then introduced. Argon is the gas recommended for steel, while nitrogen is satisfactory for the nonferrous metals.

The following explanation is given of the means by which the inert gas removes the hydrogen: "Suppose for a moment that you have a single bubble of argon inside your molten steel which is supposed to contain dissolved hydrogen. The hydrogen existing in the neighborhood of this bubble diffuses through the metal at high temperature very

*Abstract of "Usefulness and Ill Effects of Gases in Metallurgy", by E. Spire, a paper presented at the Annual Convention of the American Foundrymen's Society at Buffalo, N. Y., April 23-24, 1951.

Experimental Setup Used to Demonstrate How Size of Gas Bubbles Varies When Released Through a Tube and Porous Refractory Cone

rapidly and will penetrate it until its partial pressure in the bubble is in equilibrium with its partial pressure in solution. In other words, this bubble, which to begin with is hydrogen-free, constitutes a kind of vacuum for the hydrogen in the metal, which will then diffuse in it and will be taken out as the bubble rises." The author shows that greater efficiency may be obtained if the gas bubbles are smaller and this leads to the special method of degassing he recommends. A porous refractory is placed at the bottom of the container; this may be either the furnace or the ladle, but preferably the latter. Two illustrations, reproduced here, show a test giving the comparison between the use of a steel tube and the porous cone or plug. The efficiency of the treatment is proportional to the time of contact of the bubble with the metal and surface of the bubbles, something like 10 to 1 advantage for the smaller bubbles being suggested by the comparison of the two methods.

Not only is the method used for reducing hydrogen content, but tests with a suitable high-lime flux and the use of a finely dispersed neutral gas to bring the metal and slag into close contact required only 2% of slag to reduce the sulphur content of a ladle of steel by some 15 to 20 points in 4 min. This was done in a 5-ton ladle having an acid lining; a basic lining would give even better results.

The same principle can be used to treat molten metal with chemically active gas, to agitate molten metal with inert gas in order to activate the solution of ferro-alloys and get rid of products formed, or to homogenize a heat either chemically or thermally.

Although the work done with this process has been in connection with steel, there seems to be no reason to doubt that it could be applied to nonferrous metals, in connection with which much has been written recently on nitrogen flushing.

Harold J. Roast

The HOLE Story —by— Superior

Chapter 1

Shaping a Heart for a Pressure Gauge Requires "Technology in Tubing"

Soon after the tube pictured above comes off the shaping roll, it will be processed into a Bourdon tube, the heart of a pressure gauge, by one of our customers.

The design of a gauge movement and the skill of the gauge builder have a bearing on its accuracy. But nothing can compensate for an irregularly responding Bourdon tube.

That's where Superior comes in. The metallurgy of the tube, its dimensional precision and physical characteristics are all critical . . . and all are rigidly controlled at Superior.

This rigid control is applied to all tubing produced by Superior.

For example, in the production of seamless steel tubing for hydraulic applications, industry standards permit a carbon range of .08 to 18%. This range is not good enough for Superior. Aiming for a carbon content of .12%; Superior Hydraulic Quality tubing is always held to .15% maximum. This insistence on adherence to strict standards applies equally to dimensional tolerances.

Superior produces tubing to rigid specifications year in and year out. We have the engineers, metallurgists, research, production and test facilities that it takes to draw the highest quality small tubing in the widest variety of analyses.

You can call this combination of facilities, men, methods and machines "know-how" . . . or you can call it experience. But whatever you call it the result is always fine small tubing to do a better job for you.

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Certain analyses (.035" max. wall)
Up to 1⅝" O.D.

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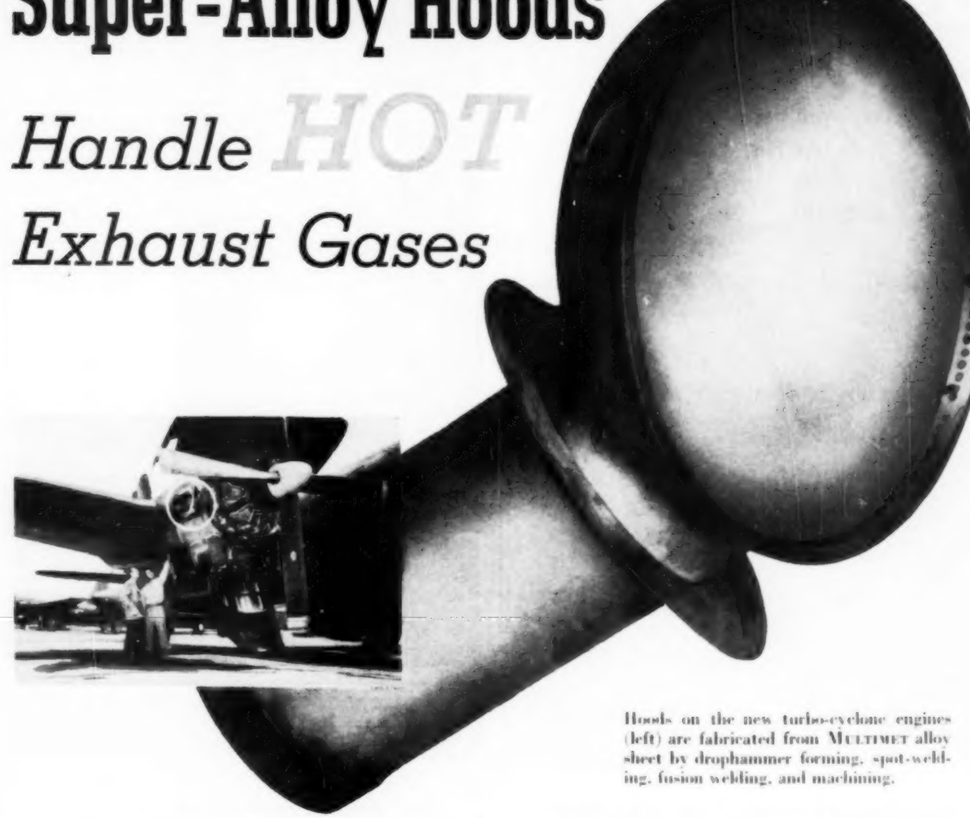
Handle HOT *Exhaust Gases*



Hoods on the new turbo-cyclone engines (left) are fabricated from MULTIMET alloy sheet by drophammer forming, spot-welding, fusion welding, and machining.

Rugged hoods of MULTIMET alloy carry off exhaust gases from the turbo-cyclone engines on this latest version of the Navy's famous "Neptune." Each hood withstands the severe heat and stress from the exhaust of six of the 18 cylinders in the engines. The exhaust is compressed into a single stream, fed through a turbine, then passes off through the hoods.

One of the reasons why MULTIMET alloy was selected for this grueling service was because it had proved so successful in gas turbines. The alloy stands up under high stress at temperatures at which other metals buckle and crack.

Besides its many aircraft applications, MULTIMET alloy is also being used in heat-treating and cyaniding equipment and other key spots where heat and oxidation cause frequent failures of most metals. It is available in all standard cast and wrought forms and can be readily fabricated by most common methods. For complete information on properties and fabricating techniques, write for the booklet, "HAYNES Alloys for High-Temperature Service."

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Pyrometer Supplies Buyers' Guide No. 100-4

Today!

IT'S NEW!

IT'S COMPLETE!

IT'S YOURS FOR THE ASKING!

HERE'S the brand new edition of the Brown Pyrometer Supplies Buyers' Guide . . . just off the press and designed to be even more helpful in your selection and ordering.

Included are standard and special thermocouple assemblies, elements and components . . . protecting tubes and covers . . . thermocouple and extension wire . . . valuable technical data and basic prices...and a host of other important information.

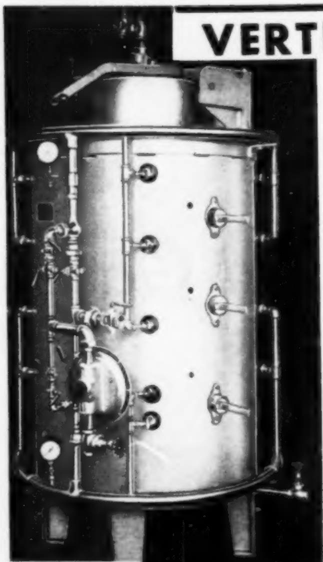
This buyers' guide is but part of the complete service available to you through your local *Honeywell Supplies Man* . . . with his HSM Plan for greater convenience and economy in all of your pyrometer supplies purchasing. Call him in for a discussion of your needs . . . he is as near as your phone. Write for your copy of this new buyers' guide today!

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Phila. 44, Pa.

MINNEAPOLIS **Honeywell**

Brown Instruments

VERTICAL RETORT GAS CARBURIZERS by AGF are PREFERRED for



shafts, gears, crank shafts, large bearing races, etc.

This is the AGF Model No. 13H Vertical Carburizer with an inside retort diameter of 15" x 32" available depth. Other models up to 48" diam. x 56" available depth.

Write for Bulletin No. 1213

AMERICAN GAS FURNACE CO

1002 LAFAYETTE STREET, ELIZABETH 4, N. J.

BUZZER *Gas* BURNERS

For Many Industrial Gas Uses

NO BLOWER or POWER NECESSARY . . . just connect to gas supply

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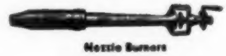

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Send for the "BUZZER" Catalog showing complete line of Industrial Gas Burners, Furnaces and other equipment.

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Every pound of dormant scrap you can furnish will help to keep the steel mills and foundries producing

Steel mill furnaces are gobbling up scrap faster than it's being delivered. To maintain planned schedules of steel production for both military and civilian purposes, the mills must have *more* iron and steel scrap.

Get in the Scrap—Yourself!

Whatever your business, you undoubtedly have scrap. If there's dust on it or rust on it—it may be scrap. If it's scrap—it's *needed.*

Turn it over to your local scrap dealer and help lick this critical scrap shortage.

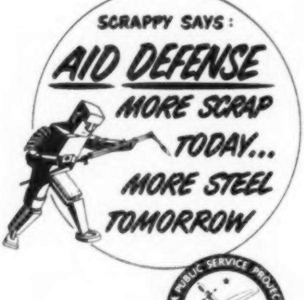
What you can do to help

1. Appoint one top official in your plant to take full responsibility for surveying the plant and getting out the scrap.
2. Consult with your local Scrap Mobilization Committee about its program to help out in the scrap crisis. The nearest office of the National Production Authority, Department of Commerce, can tell you who your local Scrap Mobilization chairman is.
3. Call in your local scrap dealer to help you work out a practical scrapping program. Non-ferrous scrap needed, too!
4. Write for free booklet, "Top Management: Your Program for Emergency Scrap Recovery", addressing Advertising Council, 25 W. 45th St., N. Y. 19.

FACTS YOU SHOULD KNOW ABOUT STEEL PRODUCTION

Steel production	1950	97,800,000 net tons
Estimated capacity	1952	119,500,000 net tons
Purchased scrap used*	1950	29,500,000 gross tons
Estimated purchased scrap requirement*	1952	36,200,000 gross tons

*All consumers



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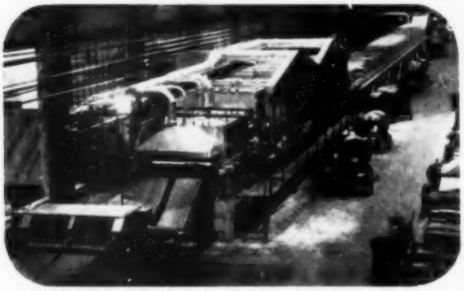

EF CONTINUOUS STRIP LINES—for annealing, galvanizing, aluminizing, etc. This combination gas-fired and electric unit provides flexibility in controlled heating, soaking and cooling, for producing various surface and metallurgical conditions on ferrous and non-ferrous strip.

EF GAS CARBURIZING FURNACES. This gas-fired radiant tube installation handles several different heat treating processes and cycles—efficiently and economically. It improved product uniformity and production control—and reduced costs.

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● EF engineers specialize in designing and building production furnaces — continuous and batch types — including roller hearth, roller rail, chain belt, wire belt, slot and tube conveyor types, reciprocating, rotary, car, bell, pit and other designs; complete with special atmosphere producers, and time and labor saving material handling equipment as required.

Reflecting more than 30 years of continuous research and experience, and outstanding engineering accomplishments, EF furnaces combine high heating efficiency, accurate automatically controlled cycles, and advanced designs that minimize maintenance, assure economy of operation, high hourly output and uniformity of product.

Submit your production furnace problems to **experienced engineers — it pays.**

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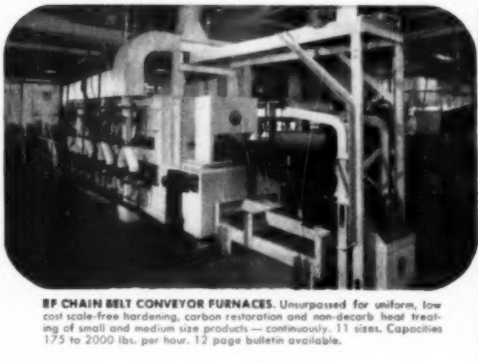

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